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APPLICATION OF ENGINEERING TO REDUCE FARM MACHINERY INJURIES IN SASKATCHEWAN

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Final Report

Application of Engineering to Reduce Farm Machinery Injuries in Saskatchewan

Derek Rude, A.Sc.T.
Project Technologist
Technical Services

Mark Ingram, E.I.T.
Project Engineer
Technical Services

Signature on file

James Wassermann, P.Eng.
Vice President
Saskatchewan Operations

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Opinions expressed in this document are those of PAMI and not necessarily the funders.

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1. Summary

A project was initiated with the primary goal of conducting two engineering initiatives to improve the safety of used agricultural equipment in Saskatchewan. A number of factors pointed to the need for this project. Injuries from agricultural machinery occur at a very high rate, and most of these injuries are caused by used equipment. Despite engineering of safer equipment being one of the preferred means to reduce injuries, there currently is limited engineering effort applied to the safety of used machinery.

An engineering review of injury research statistics led to a list of 28 possible interventions that might the have potential to reduce these types of injuries. From the Canadian Agricultural Safety Association (CASA) network, a cross-Canada team of 50 advisors, consisting of producers, manufacturers, standards committee members, regulators, agricultural safety delivery professionals, medical researchers and engineers, was assembled to provide input into selection and guide the development of two engineering interventions.

The selected interventions were an improved auger inlet guard and the development of a manual for home-built guarding of used machinery, titled *On Guard*. The auger inlet guard is designed to offer reduced susceptibility to plugging (one of the main causes of guard removal), as well as a system to easily remove the guard for bin entry and to easily install and reposition the guard. The *On Guard* manual provides an easy to follow procedure to allow producers and non-engineers to build guards, which will meet the current standards.

As part of the project technology transfer, project staff then presented the two safety initiatives to the Saskatchewan Alliance for Agricultural Health and Safety and to the Institute for Agriculture Rural and Environmental Health as well as to some producers and manufacturers. Suggestions were obtained on the best way to get the two initiatives out to the producers. For the auger inlet guard, a combination of demonstration and publicizing information was suggested. For the *On Guard* manual, a web site posting, an electronic copy for provincial adaptation and printing a run for distribution were recommended. Some of these technology transfer initiatives have already been conducted.

While doing the presentations, evaluations were also conducted. Survey results indicated that these initiatives would increase safety and that the project was worthwhile. This project had been conducted as a one-year pilot project. Based on the evaluations, it was recommended that the project be continued as a long-term national initiative focused on improving the safety of used agricultural machinery.

2. Technical Report

2.1 Background and Objectives

In the period from 1990 to 1997, 123 farm work-related deaths occurred in Saskatchewan. From 1991 to 1995, 1,835 farm injury cases were admitted to hospital with 40% resulting from farm machinery.

A similar trend exists nationally. Every year in Canadian agriculture, there are 114 deaths and 1,500 hospitalizations. This does not include the minor injuries that do not require medical care. With this number of injuries, agriculture has one of the highest rates of injury of any industry. Due to the nature of farming, there are a huge variety of injury circumstances, but agricultural machinery is the most common component involved in injury events (**Figure 1**). Agricultural machinery is a factor in half of all of the injuries.

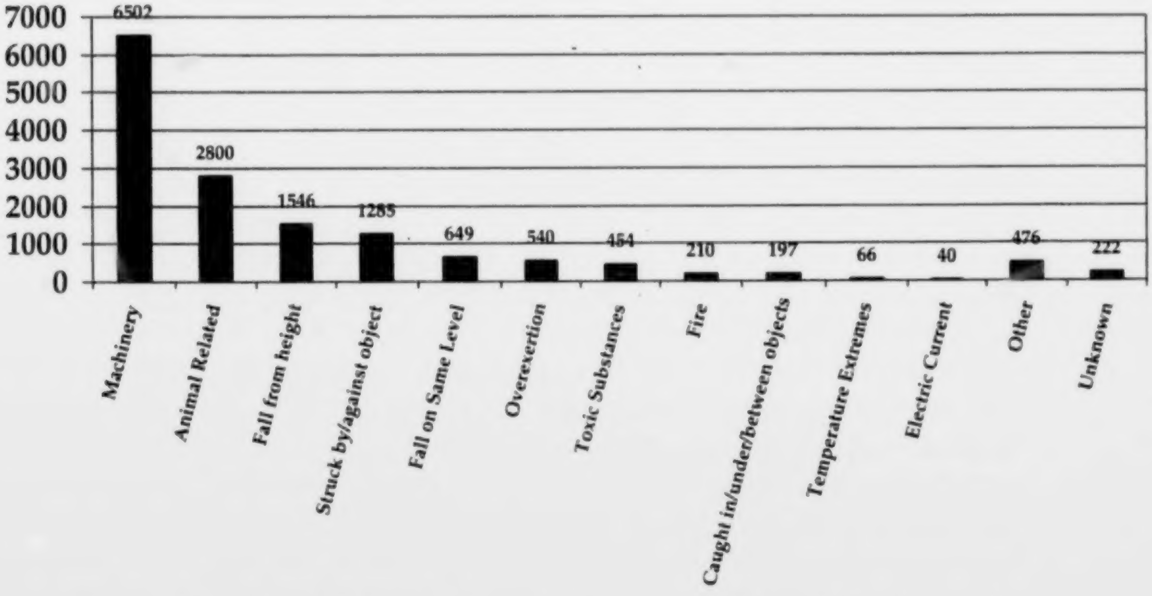


Figure 1. CAISP Data on Cause of Hospitalized Agricultural Injuries in Canada.

Furthermore, used equipment seems to be a bigger cause of injury than newer equipment. There have been many safety concerns addressed in the manufacturing of new equipment; however, much of the used agricultural equipment in use lacks safety accessories. The used equipment may lack safety devices because they were designed to outdated safety standards, due to damage or removal of original equipment. This observation seems to be supported by preliminary data coming from the Case-Control Farm Machinery Injury CCFMI study. The trends indicate that more injuries are resulting from used equipment.

Murphy (1992) stated the priorities of injury prevention activities were:

- Use engineering solutions to eliminate the hazard.
- Guard the hazard.
- Warn the users of the hazard by use of signs.
- Train and instruct the users.
- Prescribe personal protection.

The application of these priorities to injury prevention with used equipment illustrates a notable deficiency. Currently there is a network that supports the application of safety to new agricultural equipment. Specifically, the Canadian Standards Association (CSA) Standards Committee on Agricultural Equipment is currently working to develop and keep current Canadian Agricultural machinery standards, which are largely focused on safe design criteria. In addition, most manufacturers' design teams include a significant effort towards the application of these standards and other relevant safety considerations.

However, used equipment tends to receive limited benefit from these efforts. Many machines were built before existing standards were in place. Furthermore, many machines that once had design and guarding to today's standards may no longer retain those features. Guards may be removed because they were damaged and no longer fit the original attachment locations. In many cases, guards were removed for service, and because they were awkward to re-attached, were set aside and never re-attached. Even if there was intent to replace the guards later, it may not have happened because they may have been lost by then.

Some used equipment may have received some safety attention. Specifically, if the farm has employees, OHS and/or WCB representatives and committees in at least some of the provinces may have initiated safety activities. However, these agencies only have jurisdiction on those farms where there are employees and only can assist to the level of staffing they have available. Similarly, some provinces have active agricultural safety organizations, which encourage general safety related activities that could benefit operators of used equipment. However, generally speaking and especially in the area of engineering support for modification of used agricultural equipment, there is a gap.

Finally, the CCFMI study includes the use of an engineering team to perform a unique analysis. They look at machinery injury events, and in cases where the machine is used, an assessment is conducted to determine if the injury would have occurred if the machine had met today's safety standards. The data is still preliminary, but the trend suggests that many injuries could have been prevented if the machine had been up to today's standards.

In summary:

- Agricultural machinery causes over half of all agricultural injuries.
- Used equipment causes more injuries then newer equipment.
- If these machines had been up to today's standards, many injuries would have been prevented.
- Engineering is an important means to achieve injury prevention.
- There is currently no significant engineering work being done on used machinery safety.

Thus, there was a good reason to proceed with a project focused on the application of engineering to reduce agricultural injuries from used agricultural machinery.

For several reasons, the project was designed as a one-year project. While this is a very short time frame for such a potentially extensive project, it was decided to proceed but to keep in mind that this should be treated as a pilot project operating under time constraints. At the end, one could assess whether a longer-term initiative with this project theme should be pursued.

2.2 Methods

The project had a major and minor goal:

- To improve the safety of used agricultural machinery in Saskatchewan using two engineering interventions.
- To determine, based on this pilot project, if a long term initiative should be conducted using engineering to improve the safety of used agricultural machinery

The project was separated into five phases:

- Analyze and Prioritize Causes of Agricultural Machinery Injury
- Determine Two Priorities Requiring Intervention of this Project
- Improve Safety of Two Agricultural Machines or Pieces of Equipment
- Technology Transfer
- Project Evaluation & Final report

2.2.1 Analyze and Prioritize Causes of Agricultural Machinery Injury

Considerable statistical data was obtained from the Canadian Agricultural Injury Surveillance Program (CAISP) reports. These reports indicate the types of machinery involved in injuries. They also indicate the type of injury that occurred. However, the data did not include the circumstances surrounding the injury, nor any detailed information about the machinery involved. The Institute of Agricultural Rural and Environmental Health (I.ARE.H) has studied the circumstances surrounding agricultural machinery injuries in depth. A project titled "Case-Control Study of Agricultural Machinery Injuries (CCFMI)" determines how the injury actually happened and collected detailed information about the machinery involved. Other research information was obtained from Canadian Agricultural Safety Program (CASP) projects, an Alberta Auger Injury study, as well as international research including studies from Australia and the United States.

In addition, PAMI staff has been members and active participants on the CSA Agricultural Machinery Standards committee for several years. Meetings are attended twice each year. This has provided a solid understanding of the current global standards strategies at minimizing machinery related injuries.

The strategies used by regulators also played a role. PAMI has an internal Occupational Health and Safety Committee, and members on this project team also sit on that committee. The strategies of regulators were also used to optimize the project results.

Based on the available data, the engineering team developed a broad list of potential engineering interventions that could be used to reduce the number of agricultural machinery injuries related to used equipment.

2.2.2 Determine Two Priorities Requiring Intervention of this Project

This phase used the following process to optimize selection of the two priority projects that would be pursued.

Using the Canadian Agricultural Safety Association (CASA) network, a cross-Canada team of 50 advisors consisting of producers, manufacturers, standards committee members, regulators, agricultural safety delivery professionals, medical researchers, and engineers was assembled to give input into selection and to guide the development of two engineering interventions. Nine of these advisors were from Saskatchewan.

Through a teleconference call, the members discussed the list of potential projects that was compiled in Phase 1. After the discussion, a survey was sent to all the members to indicate their personal opinions as to which initiatives should be pursued.

Their selection criteria for the initiatives included:

- Work should focus on types of machinery causing most injuries.
- There should be a potential for a high reduction in number of injuries.
- There should be a high probability that farmers will utilize the technology.
- The problem is not being addressed by any current existing programs.

From that information, PAMI took their prioritized list and further applied the following selection criteria:

- There should be a high probability that a successful intervention can be developed.
- The intervention must be completed within the time frame of the project (8 months).

Based on this two-step process, two initiatives were chosen.

2.2.3 Improve the Safety of Two Agricultural Machines or Pieces of Equipment

This phase was intended to include the development and testing of two pieces of improved safety equipment.

For one of the selected initiatives, this process applied directly. This requirement was responded to by the development of a concept, the design and fabrication of a prototype, and testing followed by several refinements to the prototype.

The second selected initiative did not fall into the machine component-engineering model. Rather, the most effective opportunity was seen to be a manual that empower producers with simplified engineering standards and techniques to allow them to guard their used equipment. This intervention could then be applied to all of their used machinery. This manual was developed using several previous models including PAMI's historic Machinery Evaluation Reports, which were engineering reports on machinery performance written in a way that was understandable and meaningful to the producers.

2.2.4 Technology Transfer

It was decided that direct contact with agricultural safety representatives in each province would be a very effective way of initiating and determining the most effective technology transfer process. A Power Point presentation of the project was developed. In the presentation of the technology transfer portion of the project, some potential approaches were proposed for discussion with the safety representative. The responses of the representatives from each province were used as the final guide for the most appropriate technology transfer approach. A visit by a PAMI team was then made to each of the 10 provinces. In Saskatchewan, presentations were made to members of the Saskatchewan Alliance for Agricultural Health and Safety as well as staff of the Institute for Agriculture Rural and Environmental Health.

2.2.5 Report and Project Evaluation

This report was prepared on the project using the ADF format. Copies were to be sent to all funders and posted on the PAMI web site. Copies will also be available by mail for the cost of printing and shipping.

An evaluation form was prepared that allowed input to determine if each of the two initiatives were accepted as priorities and whether the interventions would help reduce injuries. There were also questions on whether this project, using the application of engineering to the safety of used equipment, was beneficial and whether a longer-term initiative should be conducted. Finally the question was asked about whether there were other initiatives that they would consider beneficial.

2.2.6 Administration

All written documents were translated from English to French. As PAMI was established by an Act of the Province of Saskatchewan, it is eligible to have the provincial translation service perform translation. This service was setup early in the project and was used for the *On Guard* manual. However, for the translation of the main report, there was another opportunity. PAMI was developing another research initiative with an Agricultural Engineer PhD candidate at the University of Saskatchewan. Hubert Landry is fluently bilingual, as he was born and raised in Quebec. His agricultural engineering background should result in a highly accurate translation of a technical agricultural document. He was used to translate the report and to review the *On Guard* translation.

The project also required an independent financial audit for the CARD funding. The accounting firm of Meyers Norris Penny was contracted to perform this.

2.3 Results and Discussion

2.3.1 Analyze and Prioritize Causes of Agricultural Machinery Injury

Data from all of the sources was reviewed including CAISP, CASP, CCFMI, the Alberta Auger Study, and international data. The CAISP data was very useful to provide overall analysis from Canada (**Figure 2, 3,** and **4**).

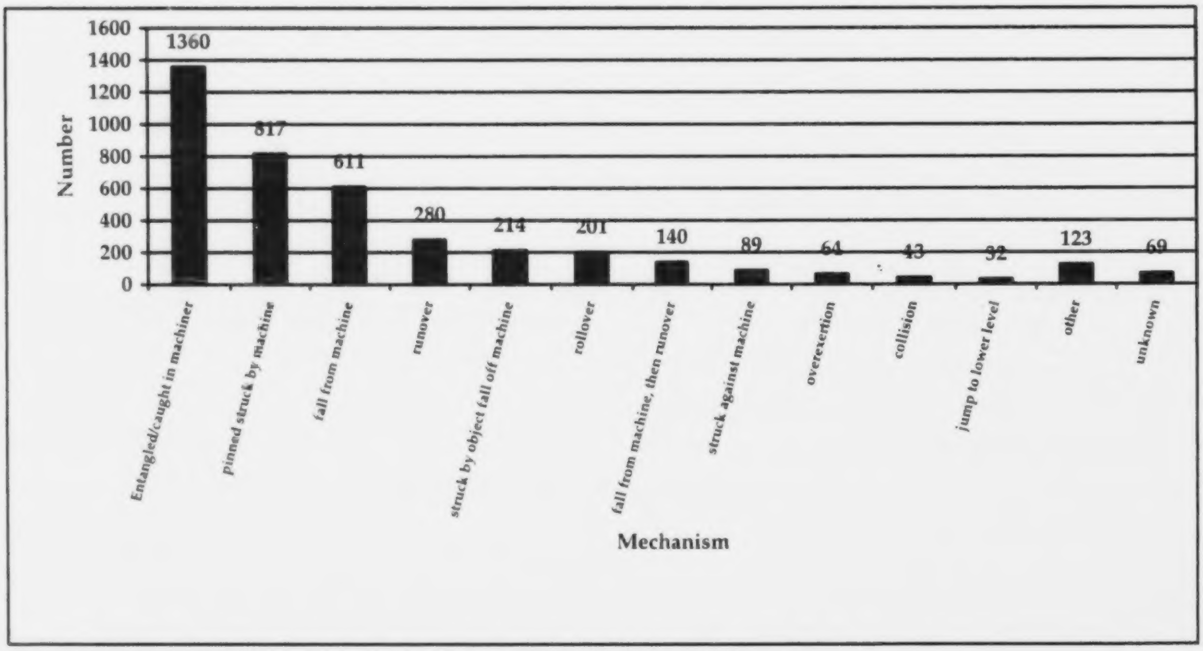


Figure 2. Hospitalized Agricultural Machinery Injuries, by Mechanism.

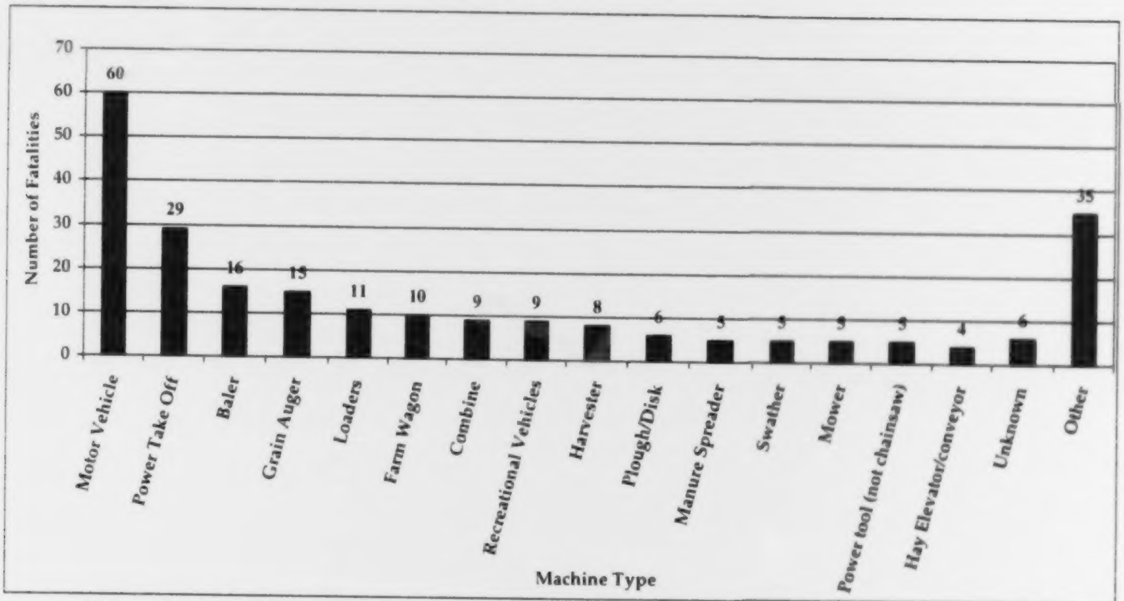


Figure 3. Work Related Agricultural Fatalities Involving Non-Tractor Machinery 1990-1998 by Machine (243 Deaths).

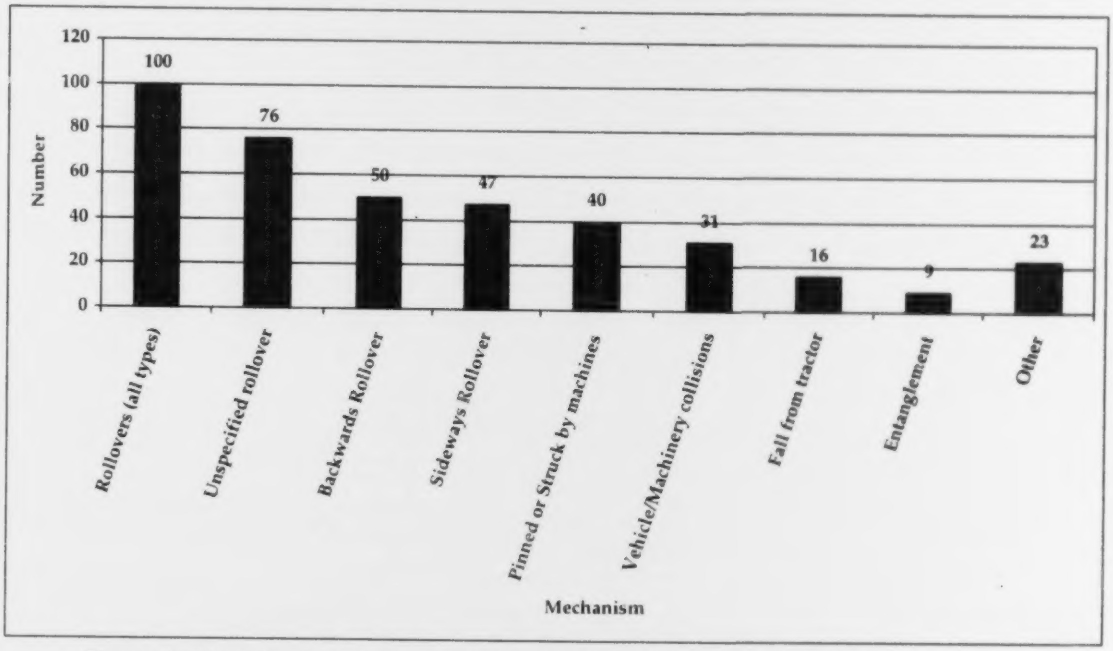


Figure 4. Work Related Agricultural Fatalities Involving Tractors 1990-1998 by Mechanism (392 Deaths).

Based on that, the engineering team on the project developed a broad list of potential engineering interventions that could be used to reduce the number of agricultural machinery injuries related to used equipment **(Table 1).**

Table 1. List of Potential Engineering Interventions.

Auger Inlet Guarding
Automatically Deployable ROPS
Improved Steps & Handrails to access equipment
Standard for PTO shield interchangeability
Replace PTO drive with hydraulic drive
ROPS Retrofit for used tractors
Handbook for Homemade Guarding
Guardrails/fall protection from high places
Safer Drag Augers/Bin Sweeps
Seat Belt Transmission Interlock
Safety Area around PTOs
Safe Passage area over PTOs
Magnetically attached guards
Travelling guard for ditch mowers
Beacon to indicate drive engaged and operator not in seat
Remote Clutch for PTOs
Convert used non-spinning PTO guards with new spinning style
ROPS on ATVs
Hydraulic drive or clutch for bottom 2 ft of grain auger
Hydraulic cylinder lockouts that are easy to engage
Easily Operated wing lift cylinder locks
Road switch to lockout certain items during road travel
Park Brake and Service Brake retrofits for used tractors
Pilot operated hydraulics for front end loaders
Standardized lighting packages
Mirror Kits for Tractors
Tractor Cab Filter Monitoring
Improve Safety of Jackalls

Then the injury data and the potential interventions were cross-referenced to result in a graph that showed the number of injuries per year that might be prevented if the intervention was completely successful (**Figure 5**).

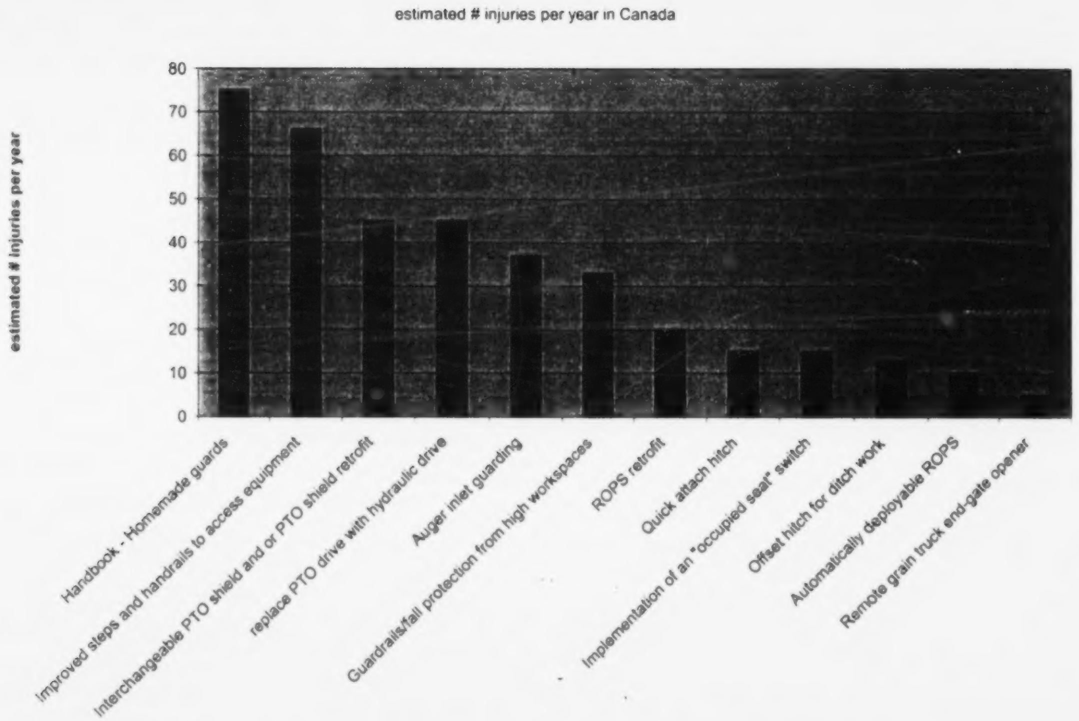


Figure 5. Relation Between Interventions and Number of Injuries Per Year.

2.3.2 Determine Two Priorities Requiring Intervention of this Project

The team of advisors was established by drawing from the existing CASA network.

Using the Canadian Agricultural Safety Association (CASA) network, a cross-Canada team of 50 advisors was established consisting of producers, manufacturers, standards committee members, regulators, agricultural safety delivery professionals, medical researchers, and engineers. Nine were from Saskatchewan. Names are given in **Table 2**, while more details including location, sector, and E-mail address are given in **Appendix I**.

Table 2. Names of Advisory Group (* = Saskatchewan).

Billy Woods	Dean Rathwell	Glen Blahey	Laurel Aitken	Rob Brison
Bob Ross*	Deborah Ehmann*	Gordon Bryant	Lawrence Manchur	Rod Scarlett
Bruce Johnson	Deborah Guillemette	Helen McDuffie*	Lloyd Evans	Roger Hoy
Cameron Bodie*	Doina Priscu	James Dosman*	Lorne Henry	Roland Kilpatrick
Carl Palmer	Don Anderson	Judy Guernsey	Lucie Lacasse	Sharon Clark*
Cathy Vanstone	Douglas Durant	Julie Bidwell*	Marilyn Affleck	Steve Zronik
Charles Everett	Elizabeth Crouse	Ken Imhoff*	Martine Mercier	Ted Whitworth
Curtis Evenson	Finbar Desir	Kieran Green	Maurice Korol	Trevor Crowe*
Dave Shanahan	Gary Mawhiney	Larry Campbell	Nicole Arseneau-Ruttan	Will Pickett
Dean Anderson	Genevieve Pickett	Larry Nason	Rick Atkins	Yves Brissette

A conference call was conducted. The graphical data, list of potential interventions, and their relation to injuries was presented. Each potential intervention was discussed and some summary information resulting from the discussion follows in **Table 3**.

Table 3. Potential Intervention Discussion.

Intervention	Discussion
Auger Inlet Guarding • Guards get removed if they don't fit through the bin door hole or restrict grain flow	• One fatality per year • 37 injuries per year involving intake end of augers • Entanglement • Suggestions to change the bin door access and hopper design, easier transformation • Convenience – if they worked, the farmers would use them • Can't clean it out, ie. Which is needed when changing from one grain to another • Accessibility, easily removed and put back on • Problems when unloading • Changes to bin door requires structural considerations • More graphic pictorials/decals on auger inlet
Automatically Deployable ROPS • Could be used by orchard or yard tractors that have fold-down ROPS	• Background work done on this in US • Probably not ready yet • Will it still function when it needs to • Stability, sensors are problematic • Similar problem to airbag development • Are questions answered and is it proved • $$ is going to be high • Challenges with new tractors will multiply to older tractors
Improved Steps and Handrails to access Equipment • Could be sold as kits • Consider plastic step kits • For entrance into cab or for fueling or other service • Standards exist	• High number of fall from steps on top heights • How serious are injuries • In MB, have had life threatening injuries, riders fall off and are run over • Consider circumstances, ie. fatique, changing operators on-the-fly • If other people are on the platform, they shouldn't be there in the first place • Don't invite them into a hazardous situation • 225 injuries/year from fall related incidents • Older farmers • Older equipment – more difficult to access • Younger people, head hitting when falling • Debris on step making steps unsafe • People of smaller stature at risk • Ladders on combines are very vertical – improvement in design

	• Allow for debris to fall through • Design may have ladder tipped toward equipment, if you were to fall you fall toward the equipment
Standard for PTO shield interchangability • Would make it more likely that PTO shields would be replaced	• Dealers don't carry the right PTO to fit • Standardized parts • Unavailability • Individual from US sells PTO shield retrofit kits • Available, more investigation (ADMA)
Replace PTO drive with Hydraulic drive • Very safe but expensive	• Two to four times more expensive • Older tractors would not have power • Pump fitted on PTO, accommodate any power level • The greater the horsepower, the greater the cost • Macleod Harvester (180 hp tractor) uses this • Need to keep the oil cool
ROPS retrofit • Program successful in Australia • Could include new seat as part of new ROPS	• Tractors are out of use • Cost effective • Unable to get parts for old equipment • Australia – ROPS cab manufacturer, five different designs of ROPS that could accommodate 80% • Could Canadian ROPS Manufacturers be interested??? • Expect this to include seatbelts; especially issue on rollbars • Older tractors not designed to hold weight on rear axle • Recommendation – focus with tractors designed to have ROPS but not equipped with one • Should the seat be attached to the ROPS? • Problematic • Four post
Handbook on Homemade Guarding • Tips on making effective and practical guards • User friendly interpretation of existing standards, much like "be seen, be safe"	• Doesn't see farmers making guards • Handbook for producers that appeal to them • Would allow them discretion on how to deal with issues • Reflect critical concerns and issues • Offer guidance, but allows ownership • Continuing effort • Tips, good idea • US, litigation concerns • Agriculture related publications • Utilize these to include technology transfer

Guardrails/fall protection from high workplaces • Platforms and railings for combines, airseeders, etc.	• Could come into handbook • Injuries more severe fall from high places versus steps • Older machine issue • Include gritty material to reduce slippage, secure footing • Be Seen, Be Safe approach • Good effort going into new machines • More focus going into older machines
Safer Drag Augers/Bin Sweeps • Adjustable relief to stall auger if obstruction encountered	• Smaller number in terms on injuries
Seat Belt Transmission Interlock • ROPS are ineffective if seat belt not used • Incorporate with existing neutral safety switch • Engine off if not in neutral and seat belt not on	• Incorporate safety switches to connect to seat belt • ROPS on tractors versus seatbelts • Can't reach them for maintenance, so they jump start them, make for more dangerous situations • Education in handbook • Only safe as long as it works • Get opinion from someone in automotive
Safety Area around PTO's • Use light beams or other non-contact method to detect intrusion and sound alarm • Maybe incorporate delay that will shut off engine after 10 seconds of intrusion	• Light beam sensor • Problems, debris shutting it off • Warning before shut off • Check with Mining • Consider environment for effective approach • Manufacturer concerns, don't invite the farmer into an unsafe situation • Don't just reduce injuries, eliminate the injury
Safe passage area over PTO's • Bridge with good steps and railings	• Will not be simple; may not be practical
Magnetically attached guards • Would increase likelihood of guards being replaced after removal for servicing or repair	• Ease in removal • Discussion in Europe with tether guards • Load requirement • Interference with other magnetic sensors • One corner with mechanic link, other three corners with magnetic
Travelling Guard For Ditch Mowers. • Side guard that would follow contour of land to stop objects from being ejected toward passersby	• Skid along plates, keeping it to the ground when mower is tilted in ditch
Beacon to indicate drive engaged and operator not in seat. • Would remind people beside machines that machine is still under power and not just coasting down	• No Comments

Remote clutch for PTO's - Would make engaging and shutoff possible from ground level	- May invite people into hazardous situation
Convert older non-spinning PTO Guards with newer spinning style - Older guards were attached to shaft - Could also include replacement of guards that no longer spin due to damage or wear	- Tied into standardization of PTO shielding
ROPS on ATV's - Many ATV's now used for crop surveying and other farm duties	- Weight of ROPS may make ATV more apt to tip and reduce overall safety - Most ATV injuries probably not work related - Limit speed - Complex problem
Hydraulic drive or clutch for bottom 2 ft. of grain auger - Because only bottom section driven, easier to set breakaway torque	- Has been done before, limited success - Known as boot save - May invite into a hazardous situation
Hydraulic cylinder lockouts that are easy to engage - For cultivator wing lift cylinders, front end loader cylinders etc.	- Today's machine has - More focused on older ones - Not 100%, but better than not having them on there
Easily operated wing lift cylinder locks - Lever operated from hitch or other location far from wings	- No comments
Road switch to lockout certain items during road travel - Ie. Header lift & unloading auger on combine - Reduce chance of inadvertent machine movement during transport	- Standard feature on one new combine aware of - Difficult to fit onto older machines - Has there been a problem, are we fixing a minor problem - Not that common, but it has happened - More on tractors - Older machines - More focused on older machines
Park Brake and Service Brake retrofits for older tractors - Many older tractor have brakes that are inadequate or not operating	- How are they going to do this?? - Is an issue of keeping existing brakes revised - Retrofit would be very complex
Pilot Operated hydraulics for Front End Loaders - Fairly standard on new industrial loaders - No high pressure lines close to operator - Loader will not fall if a hose breaks	- Frequency of related injuries - Not common, but it has happened
Standardized lighting Package - Would include marker, turning and extremity lights as well as control box - Would only need 12 vdc from tractor - Would be adaptable to many towed implements, such as cultivators, bale wagons, augers, etc.	- Need to conform to ASAE Standard - Provide appropriate marking - Aren't there some on the market?
Mirror Kits for Tractors - Extendable mirrors for towing wide loads	- Practical, manageable - Could you maintain them?

Tractor Cab Filter Monitoring • Filters can become loaded with chemical residues +/or bacteria	• Complex Area, point of a lot of debate • Difficult to ensure every part of entire system (including cab) is air-tight always. • CSA Standards committee – common discussion • Filter out chemical residues • ASAE Standard • Still requirement of operator to wear PPE • Constant certification and re-certification • Not machinery injury, toxic injury, but solution could be mechanical
Improve Safety of Jackalls • A very versatile farm tool that can be dangerous if not used properly	• Not safe "anytime," Not stable • Use other forms of jacks and blocks

The discussion was recorded and circulated to the advisory group. They were asked to prioritize the potential interventions based on:

- Their estimate of injury reduction (High, Medium, & Low).
- Likelihood of usage by producer.
- Is the area already being addressed?

The results of the vote were tabulated (**Table 4**).

Table 4. Advisory Group Voting Summary on Interventions.

Intervention	**Votes (%)**
PTO guarding	20
Auger inlet guarding	17
Other general guarding	11
Access steps/ hand rails	11
ROPS / seatbelt retrofitting	8
Standardized lighting packages	6
Mirror kits for tractors	6
Tractor cab filter monitoring	5
Improve safety of Jackalls	5
Other*	11

* The highest number of votes for any particular other initiatives was 3%

To that prioritized summary, PAMI applied the criteria of:

- Completion within project timeframe.
- Likelihood of a successful engineering intervention.

Despite being the top priority, the PTO guarding project was not chosen due to the fact that the problem was bigger than could be addressed in this project timeframe. It would require significant interaction with manufacturers and extensive cross-Canada data collection, so it was not selected. However, PTO entanglements are a large problem in Canada. In fact, CAISP has a separate category for PTOs. PTO guarding is a problem that should be addressed in some future initiative.

Auger inlet guarding was chosen because it had the second highest votes, it can be addressed by engineering, it is the cause of a high number of injuries, and often these injuries involve amputations.

General guarding was third on the priority list, so it was also selected. Most new equipment is guarded well, but considerable used equipment still in use is not guarded well.

Although not on this priority list, ROPS was an important theme in the data, as well as in discussion. It did not make the above list because most advisors readily understood that this would take a significant initiative beyond the scope of the project, but clearly, it is an area that would have major injury reduction benefits if addressed successfully in the future.

2.3.3 Improve the Safety of Two Agricultural Machines or Pieces of Equipment

2.3.3.1 Auger Inlet Guarding

At first observation, the cause of auger injuries is not apparent. When observing new augers on a machinery lot, you would typically see that auger inlets are covered with considerable guarding along with warning decals that encourage safe practices and procedures (**Figure 6**).

Figure 6. Guarding of Inlets on New Augers.

However, further observations of augers on farms and at locations such as machinery auction lots would reveal a different picture of the inlet. Many completely unguarded auger inlets are found (**Figure 7**).

Figure 7. Typical Unguarded Auger Inlet.

The reason for the large amount of unguarded auger inlets was investigated. It was found that either guards have never been installed on used models, or the guard had been removed and had not been reinstalled. This second reason was quite surprising, so it was further investigated. The reasons for removal were:

- The guard reduced capacity.
- The guard caused bridging.
- The guard did not fit into bin hole doors.
- The guard's size made it difficult to push the auger into piles of grain.
- The guard made it difficult to service the inlet.

All of these situations would only point to short-term removal, but it appeared that once the guard was removed, there was a reluctance to replace it.

The above points were researched.

In searching for a solution, it was useful to understand the auger inlet guarding standard. The ASAE 463 standard states that:

> "The intake shall be guarded or otherwise designed to provide a deterrent from accidental contact with the rotating flighting. The guard shall cover the top 180 deg of the inlet area and extend a minimum of 64 mm (2.5 in) above and below the exposed flighting. Openings in the guard, for the free flow of material, shall have their largest dimension no larger than 121 mm (4.75 in). The area of each opening shall be no larger than 6450 sq mm (10 sq in). The guard shall be no closer to the rotating flighting than 64 mm (2.5 in) and be of sufficient strength to support a 123 kg (270 lb) person without permanent deformation **(Fig. 8)**."

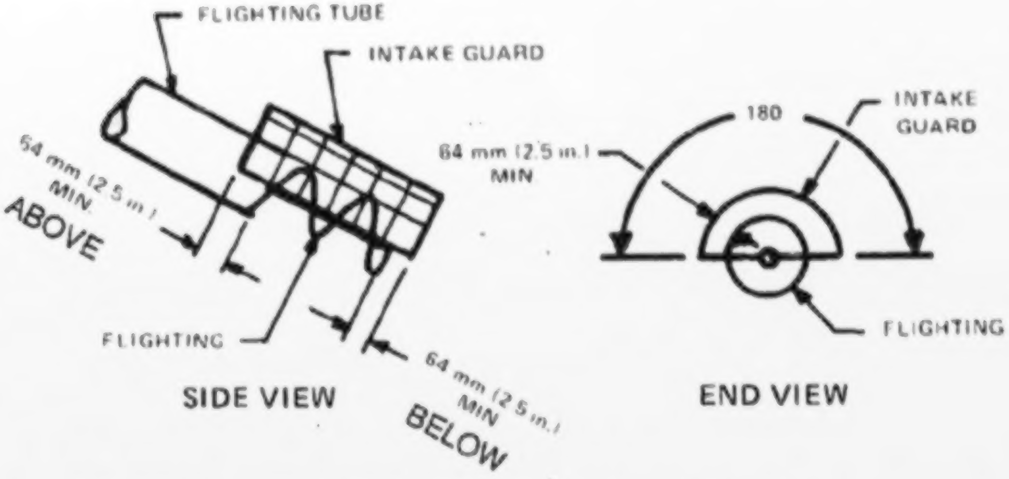

FLIGHTING TUBE
INTAKE GUARD
64 mm (2.5 in.) MIN.
ABOVE
FLIGHTING
64 mm (2.5 in.) MIN
BELOW
SIDE VIEW
180
64 mm (2.5 in.) MIN
INTAKE GUARD
FLIGHTING
END VIEW

Figure 8. Auger Intake Standard Requirements from ASAE Standard 361.3.

Capacity/Bridging: First the capacity/bridging issue was investigated. Capacity was measured using a Brandt 6" auger, a small plastic triangular hopper on the inlet, a grain truck, and a hopper bottom bin on a scale. The test used clean wheat, clean barley, and extremely "dirty" mixture of barley, chaff, and straw (**Figures 9** and **10**).

Figure 9. Barley/Chaff/Straw Mixture.

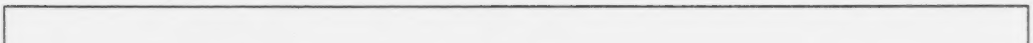


Figure 10. Effect of Grain Type on Capacity Compared to No Guard (%).

This showed that in clean grain, there is virtually no reduction in capacity, hence no reason to remove the guard. However, in dirty grains, especially if there is considerable straw, there will be some bridging that will annoy operators and encourage them to remove the guard. Thus alternate designs were pursued that would reduce the susceptibility to bridging. Such designs would focus on the extreme condition using the barley/chaff/straw mixture.

The standard guard has bars that form rectangles. Some bars run parallel to the auger tube and some run perpendicular to them. The terms "parallel" and "perpendicular" will be used in the following section to describe orientation of the bars in different designs of guards. In developing these new designs, there will always be attention paid to the auger inlet guarding standard as it would be difficult to recommend a design that did not at least meet with current guarding standards.

Firstly, a design was developed called the "Parallel" guard (**Figure 11**). It had only parallel bars and no perpendicular bars. It was thought that removal of all perpendicular bars would reduce bridging of straw. However, removal of perpendicular bars would produce a guard that did not meet the auger-guarding standard. By decreasing the spacing of the parallel bars, this guard then met general guarding standards. Unfortunately, in the barley/chaff/straw mixture, it plugged almost immediately (**Figure 12**) and was considered unacceptable. (The auger inlet guarding standard is more open than general guarding standards, and this test showed why this is required as a practical balance between personal protection and not inhibiting the function of the machine.)

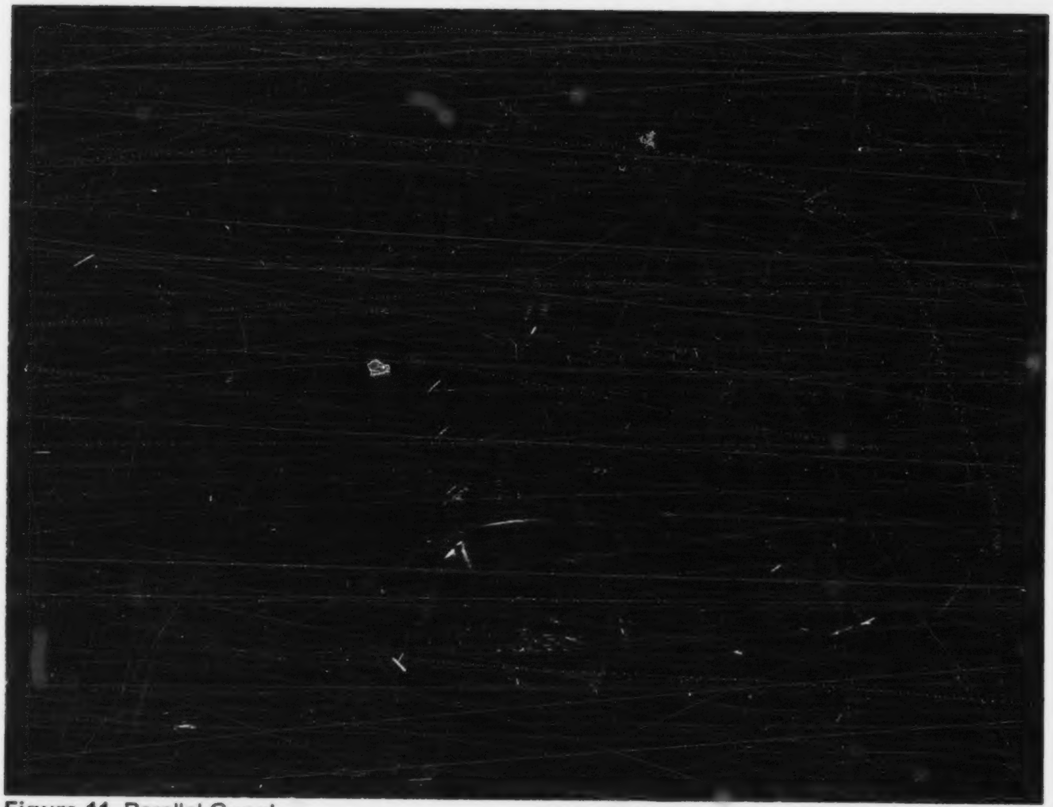


Figure 11. Parallel Guard.

Figure 12. Bridging of Barley/Chaff/Straw over the Parallel Guard.

The next concept pursued was derived from looking at the standard guard directly from above. This would be the direction that grain would flow towards the guard. It was noted that as the guard wrapped around the inlet, the "effective" area, as seen from directly above, decreased as the rectangles obtained a more vertical angle. A way to eliminate this "reduced" cross section was discussed. From that, a "Square" guard was developed (**Figure 13**). The entire upper surface had maximum "effective" open area. However, when tested in the barley/chaff/straw mixture, it quickly bridged (**Figure 14**) and was considered unacceptable. (For future designs, this may have shown that the upper faces of the guards should be angled rather than perpendicular to the grain flow direction; possibly breaking up any "mats" of material that had developed.)

Figure 13. Square Guard.

Figure 14. Bridging over Square Guard.

While not adhering to the standard, another guard was developed based on two levels of bars. All of the perpendicular bars were removed from the standard guard, and then a second set of longitudinal bars were installed that were 2.5 in (7 cm) out from the original bars and in between the original longitudinal bars. This was called the "Two Level – Parallel" guard (**Figure 15**). This displayed excellent product flow and very good resistance to bridging.

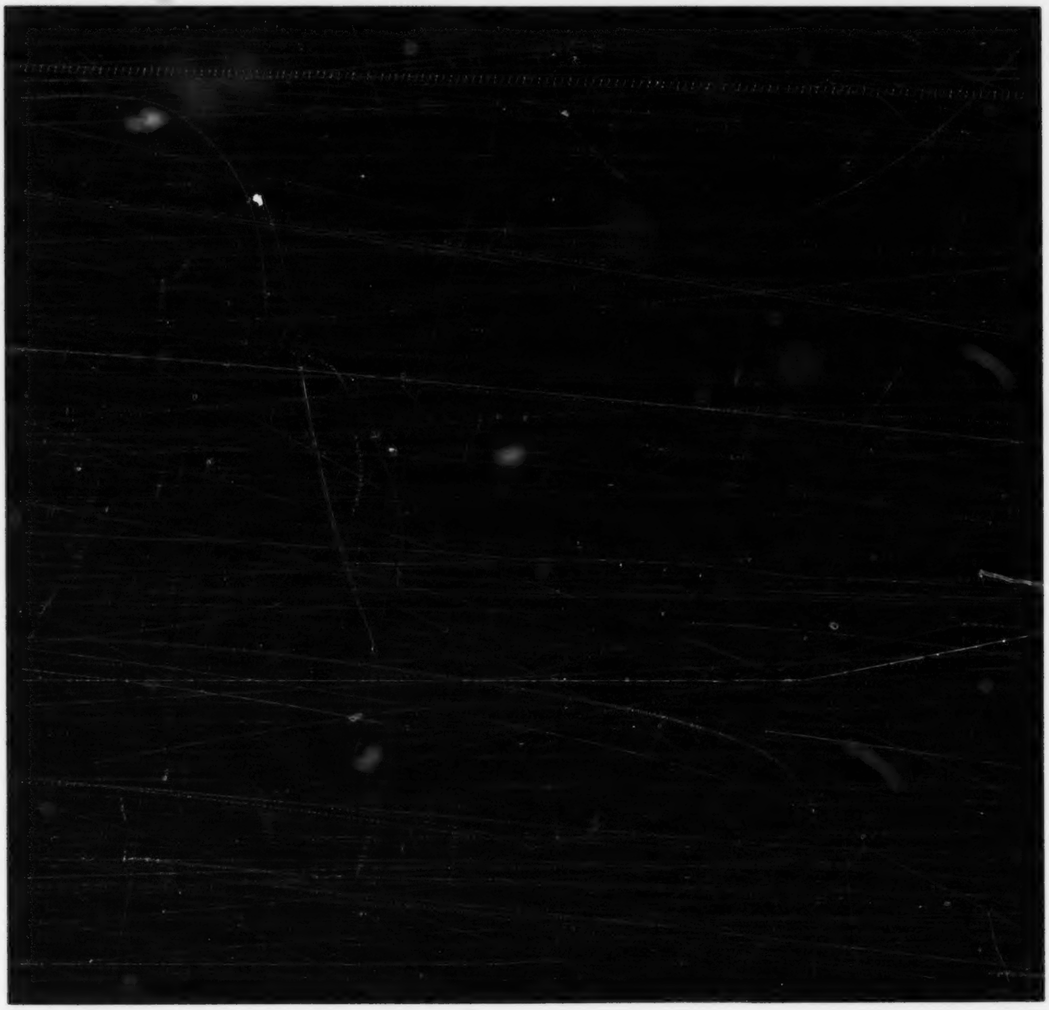


Figure 15. Two Level-Parallel Guard.

However, because it did not comply with the standard, it was further modified to meet the standard. This was accomplished by welding perpendicular bars in on the required spacing. These bars were angled to the flow of product, and when tested, showed very good resistance to plugging. In end view, this guard had an outline that resembled a "star" so it acquired that nickname (**Figure 16**).

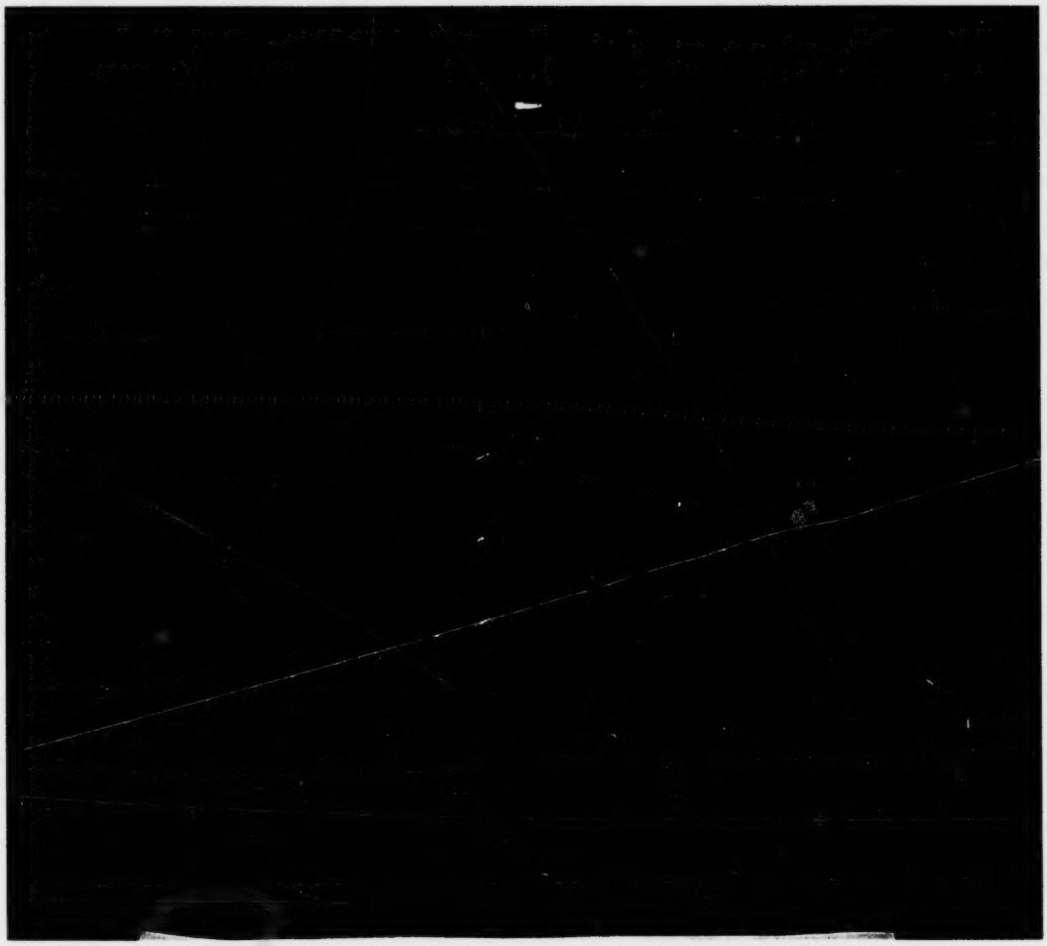


Figure 16. Welded Star Guard.

This would be very difficult to manufacture. It was found that auger manufacturers acquire their guarding material in sheets of pre-fabricated rectangular wire grids. These rectangular grids 3 x 3 in (75 x 75 mm) meet the standard. A section of this wire grid was obtained. It was bent into the shape of the welded Star Guard and then with very little reinforcement, it was attached to the auger (**Figure 17**). Testing revealed that it retained the desirable characteristics of not reducing flow rate and having very good resistance to bridging (**Figure 18**).

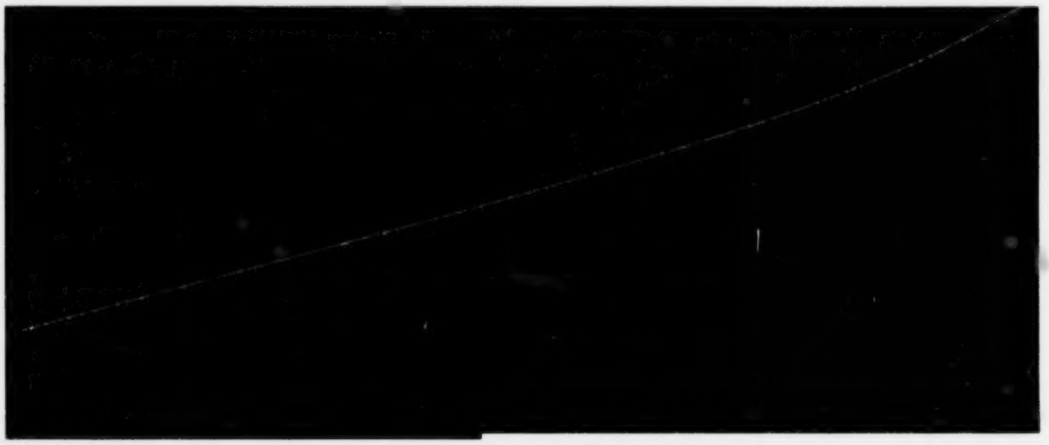


Figure 17. Wire Mesh Star Guard after Shaping and Installation.

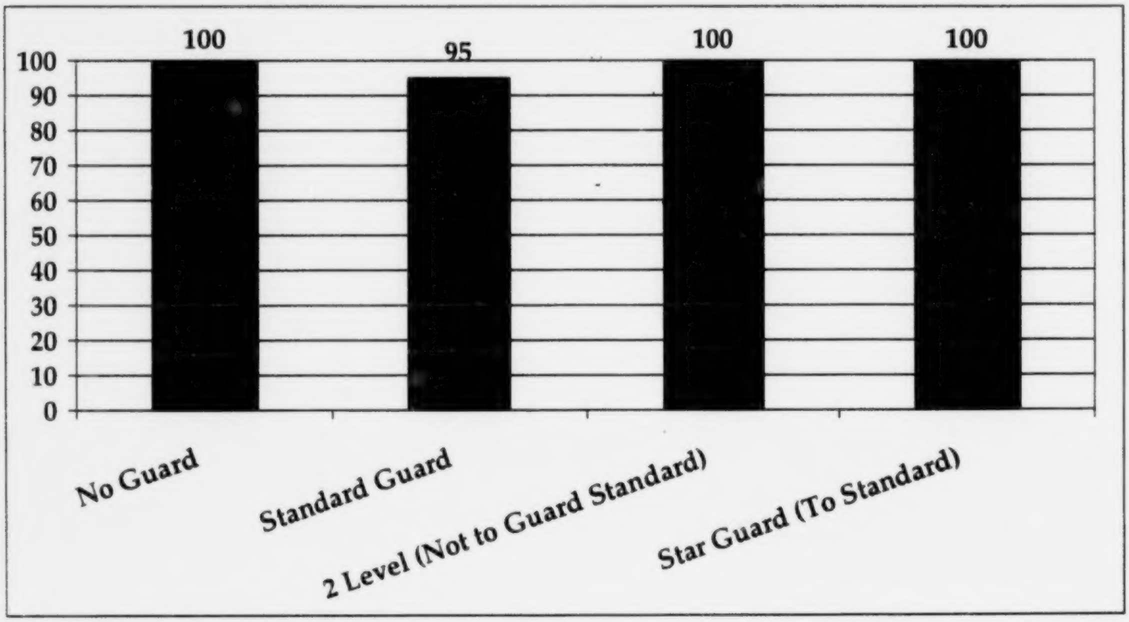


Figure 18. Capacity/Bridging of Various Guards.

The resistance to bridging was very good in the barley/chaff/straw mixture used in the PAMI tests. This is considered an extreme situation. However, depending on individual circumstances, one may still encounter a product, which could have very long straw in it that would cause bridging. While it may be possible to develop a guard that could be even more resistant to bridging, it could be a very complex and expensive result that is unnecessary for the vast majority of the time. Even in most situations, the standard guard does not cause bridging so if working with clean grain all of the time, it would not be necessary. All of this points to the need, even if just on a very infrequent basis for the guard to be easily removed out of the way.

Other Reasons For Guard Removal: The most common reason for guard removal was because the auger inlet with a guard attached would not fit into the bin door hole. Even if the guard was a smaller diameter than the bin door hole, the angle of the auger did not usually line up with the angle of the tube inside the bin door hole (**Figure 19**). Many newer bins have a more open style of auger entry but if even just one bin on the farm has the used style, the guard will likely be permanently removed.

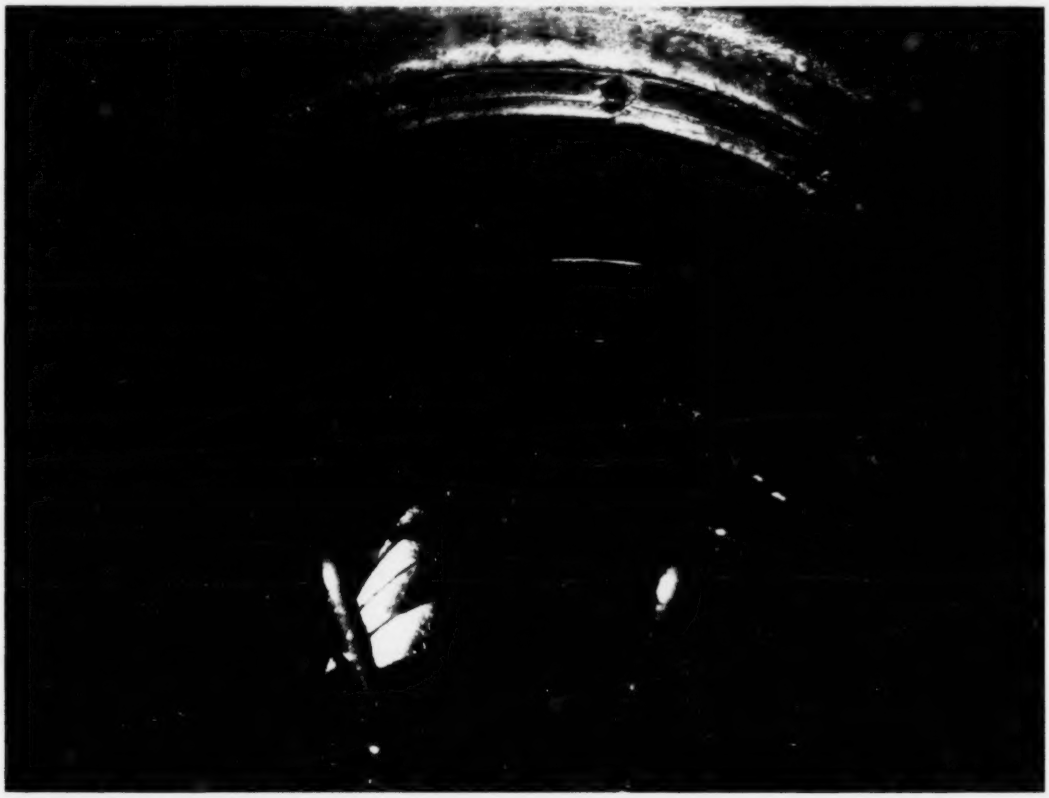


Figure 19. Bin Hole Entry.

It was also reported that guards may be removed if the producer needs to auger from piles of grain. It was stated that an auger with a guard is much more difficult to push into a pile of grain. Tests were conducted to determine how much more difficult it was to push an auger into a grain pile with and without a guard on. The test was conducted with and without the auger running (**Figure 20**). This demonstrated that the auger with the guard in place would take an extra person to move, which once again would encourage guard removal.

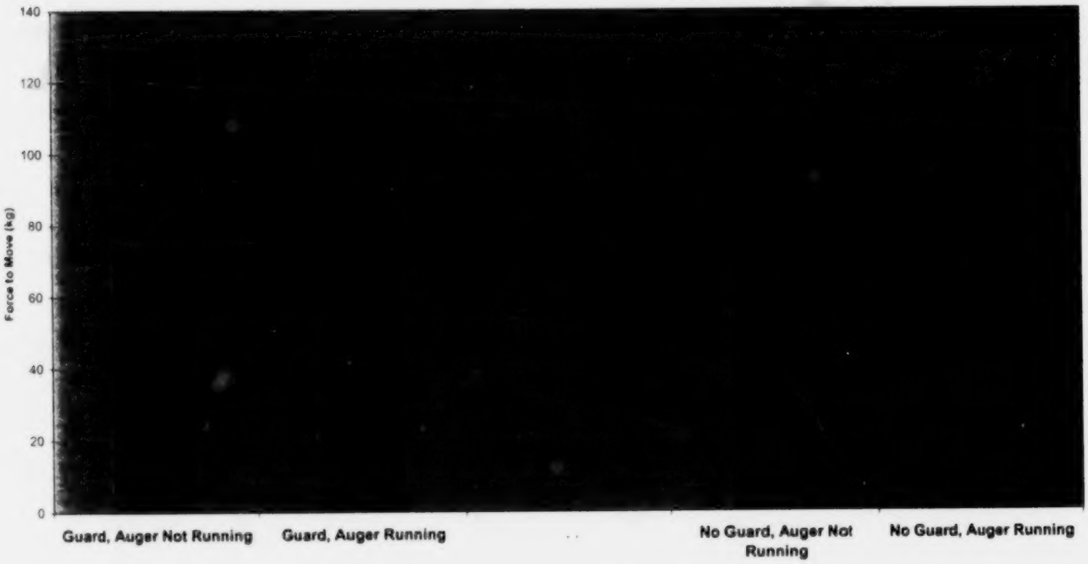


Figure 20. Force to Push an Auger a Pile of Grain.

Finally, any standard requirement to access the auger inlet for service or repair would encourage removal.

Once removed for any one of the above many reasons, there was a tendency for the guard to be left off. This could be largely attributed to the amount of effort required to replace the guard. Many guards require bolts to replace them and some are welded on, which would require a welding procedure to replace the guard. One can understand the manufacturer's perspective as they are trying to encourage the producer to leave the guard on permanently. However, the producer will usually encounter a reason to remove it, and then the difficulty of replacement coupled with the hectic schedule of producers might lead to leaving the guard off.

Based on the existence of requirements for guard removal, a design was pursued that would allow for very easy removal and an especially easy replacement process. Furthermore, it was hoped the design would allow for easy installation to retrofit augers that did not currently have a guard. To parallel the theme of current machinery guarding standards, it was also intended that the guard would always stay attached to the auger, even when not in location over the inlet. However, the guard would need the ability to be moved a considerable distance from the inlet so that it would not interfere with entry into bins or piles of grain. It would need to be a durable system so that it would withstand the rigor that auger inlets encounter. Finally, it would ideally need to be a flexible design so that only a few models would be needed to cover the wide array of grain augers currently in use without guards.

Several options were considered but finally, a design with the nickname of "Quick Move Collar" was selected. The guard is attached to an adjustable collar that can slide up and down the lower portion of the auger tube. An over-centre catch (**Figure 21**) will clamp the collar (when needing to be held in a position) or loosen the collar (when needing to move it). In the lower position, (**Figure 22**), the guard covers the inlet. However, it can slide up to 6.5 ft (2.0 m) (**Figure 23**) back from the intake when the guard needs to be moved out of place. There is a guide rod that keeps the unit from rotating so that it can only move linearly. There are also stoppers so that the intake guard cannot slide off the intake end. To discourage subsequent removal, it is much easier to use the over-centre catch to reposition the unit on the auger than to remove it from the auger. To initially install the unit on the auger, only requires the tightening of three bolts. Two small legs on the bottom of the guard will rest against the top two auger inlet support bars so that the guard, when in position, can withstand the required force of 270 lb (123 kg). Finally, a handle is attached to the collar so there is a convenient place to hold the auger when moving. (Many used augers have no convenient place to hold onto for moving augers so the tendency is to grab onto places at the bottom that expose your hand to the sharp flighting and risk a cut.)

Figure 21. Over Centre Lever Mechanism used to Hold or Loosen the Collar.

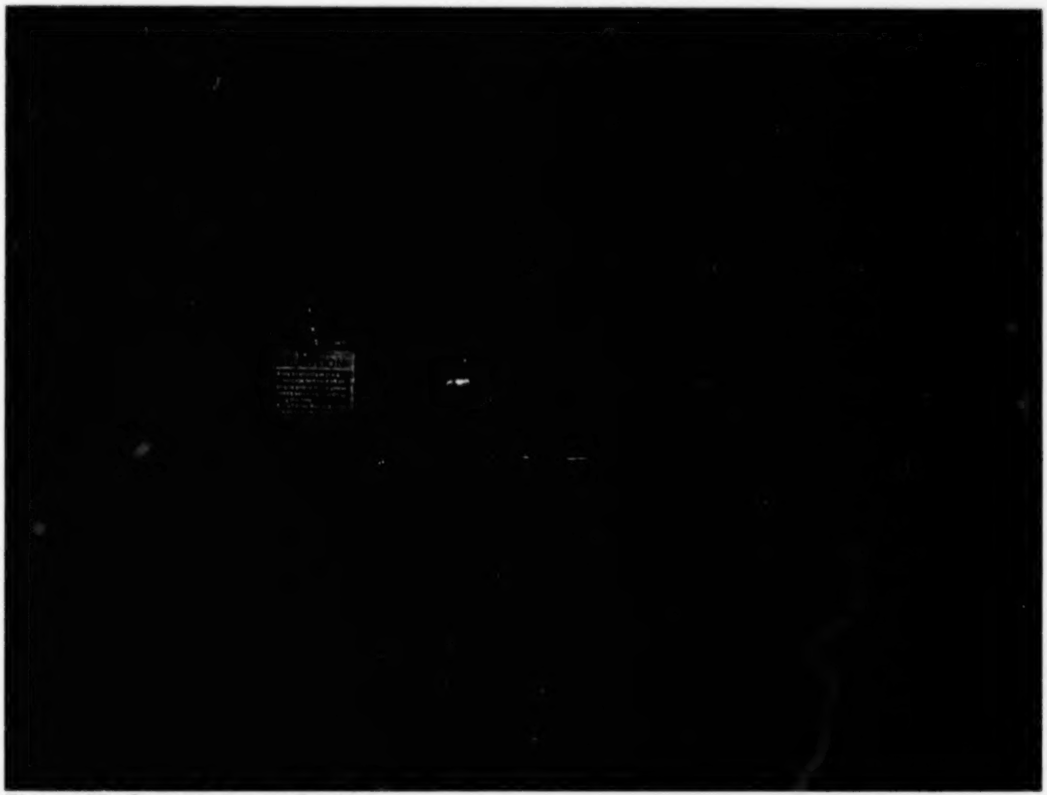


Figure 22. Guard in Lower Position.

Figure 23. Intake Guard in "Raised" Position.

Further methods were incorporated to encourage keeping the guard in place whenever appropriate. The section of auger tube under the lower collar location was painted a contrasting color (**Figure 24**). This offers a notable reminder whenever the guard is out of position. Also a warning decal was attached to the collar.

Figure 24. Contrasting Color at Lower Collar Location.

In summary, the "Quick Move Collar" guard allows the guard to be moved in and out of position in seconds while always staying attached to the auger so that it will not be misplaced.

The "Quick Move Collar", when attached to the standard guard in clean grain situations or to the Star guard in dirty grain conditions, addresses all issues initially identified in the study. A final safety audit is being conducted by various safety agencies from across Canada.

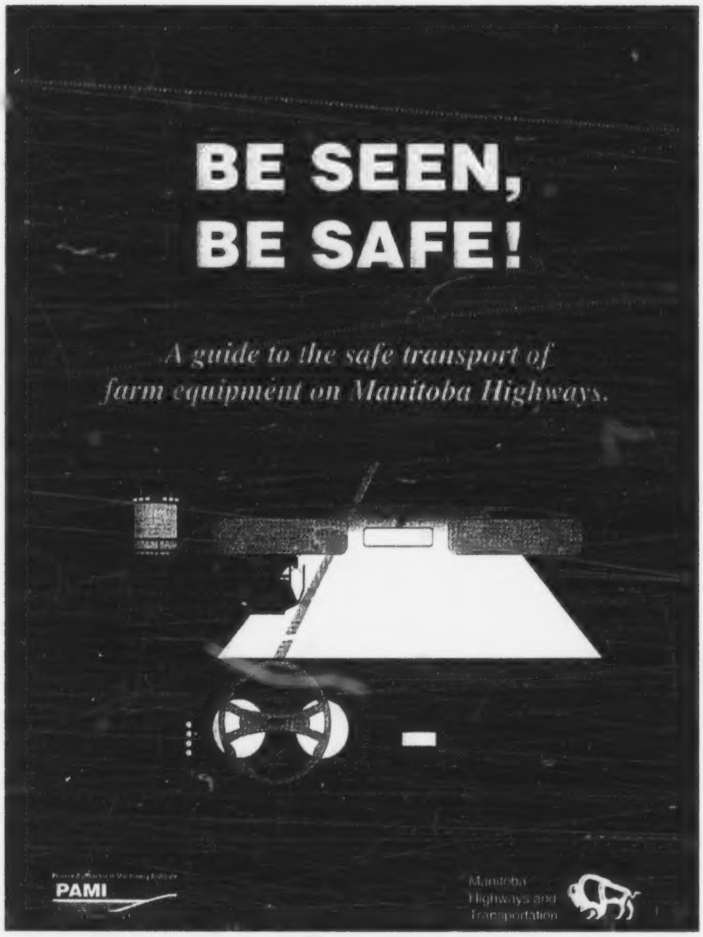
2.3.3.2 Homemade Guarding Manual

The data and the advisors showed a clear need for improving the guarding on used machinery. However, the challenge was determining what technology to apply. Generally, guarding for used equipment is either not available, or it is difficult to find. Even in the cases where the purchase of a new guard was an option, it was felt that some producers would find the cost prohibitive when comparing it to the value of their equipment. Development and manufacture of generic "no-name" guards did not seem practical, as there would be an infinite number of designs to make. Storage and distribution would be extremely complex and probably elevate the price into an unacceptable level.

There are numerous documents written to guide the guarding of agricultural equipment. They are generally Engineering Standards (**Table 5**) that are thorough but unfortunately very complex and difficult to understand. However, a previous Manitoba/CASP project had set a successful precedent. In that project, the CSA Standard for Lighting and Marking of Agricultural Equipment had been translated into an easy to read pamphlet to easily guide producers. The pamphlet was titled "Be Seen Be Safe" (**Figure 25**). It has since been adopted by many other provinces. Also, a version for the USA has been written.

Table 5. Engineering Guarding Standards.

CSA Standard Z432-94	Safeguarding of Machinery
ISO Standard 14120	Safety of Machinery: Guards
ASAE/ANSI Standard S493	Guarding for Agricultural Equipment
U.S. Dept of Labour Standard 1928.57	Guarding of Farm Equipment
Various EN Standards (Europe)	



BE SEEN, BE SAFE!

A guide to the safe transport of farm equipment on Manitoba Highways.

PAMI

Manitoba Highways and Transportation

Figure 25: "Be Seen Be Safe."

Based on this principle, a guarding handbook (**Figure 26**) was developed as a producer-friendly interpretation of various guarding standards that are applied to new agricultural machinery. The title is "On Guard!" The subtitle is "A handbook for home-built guarding of agricultural machinery." The objective is for farmers to guard their used machinery so that it adheres to new agricultural machinery guarding standards. It will allow them to use their skills in fabrication to develop their own low cost custom guards. As well, it will likely help to build an attitude of safety.

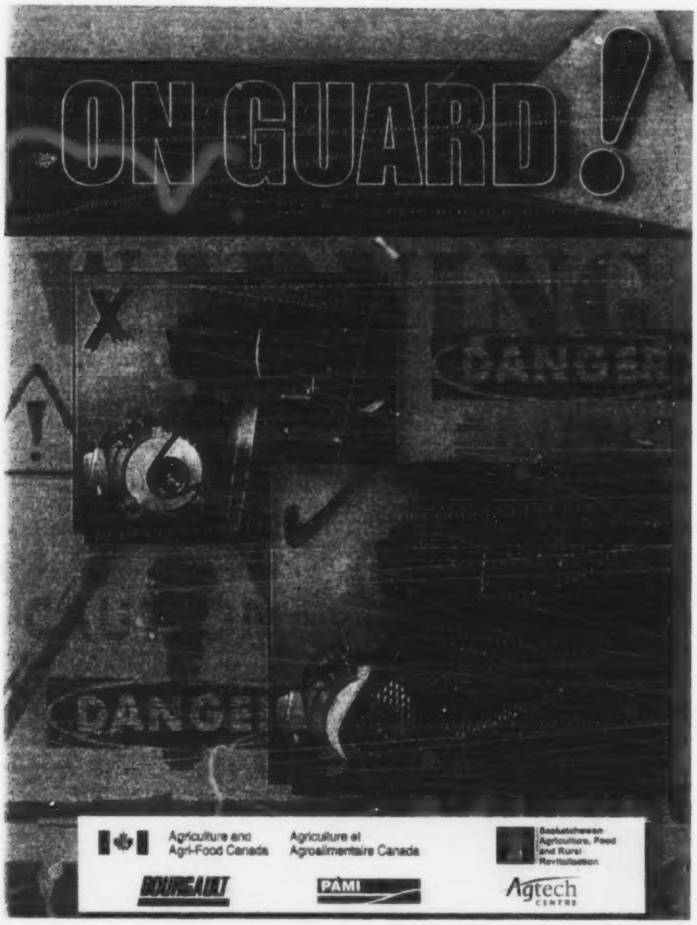

ON GUARD!
DANGER
DANGER
Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
Saskatchewan Agriculture, Food and Rural Revitalization
BOURGAULT
PAMI
Agtech CENTRE

Figure 26. The *On Guard* Handbook Cover.

The manual has four main sections:

- The first section (Fast Track User's Guide) gives a brief introduction of the book's purpose and how it was developed. It outlines the guarding procedure developed by PAMI.
- The second section (Detailed User's Guide) explains in detail the guarding procedure. It contains more technical information and example pictures related to guarding of agricultural machinery.
- The third section (Guard Design and Fabrication Example) follows the guard procedure while guarding an electrically powered grain auger.
- The fourth section contains appendices with additional technical information from standards, terminology, lists and prices of guarding components, decals, and a guarding procedure worksheet for farmers to copy.

Features of the pamphlet are shown in **Figures 27** to **31.**

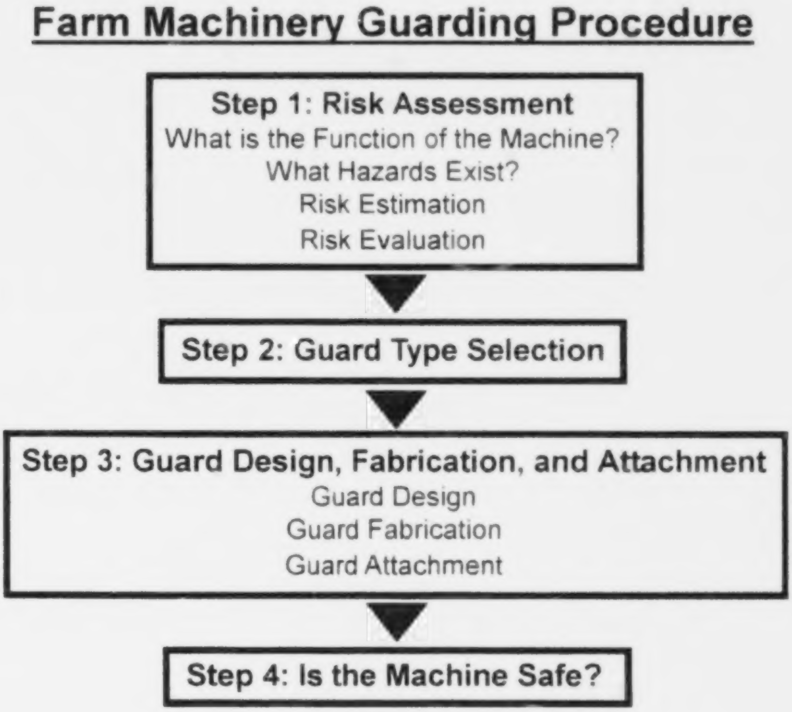

Farm Machinery Guarding Procedure
Step 1: Risk Assessment
What is the Function of the Machine?
What Hazards Exist?
Risk Estimation
Risk Evaluation
Step 2: Guard Type Selection
Step 3: Guard Design, Fabrication, and Attachment
Guard Design
Guard Fabrication
Guard Attachment
Step 4: Is the Machine Safe?

Figure 27. Graphic of the 4-Step Guarding Process.

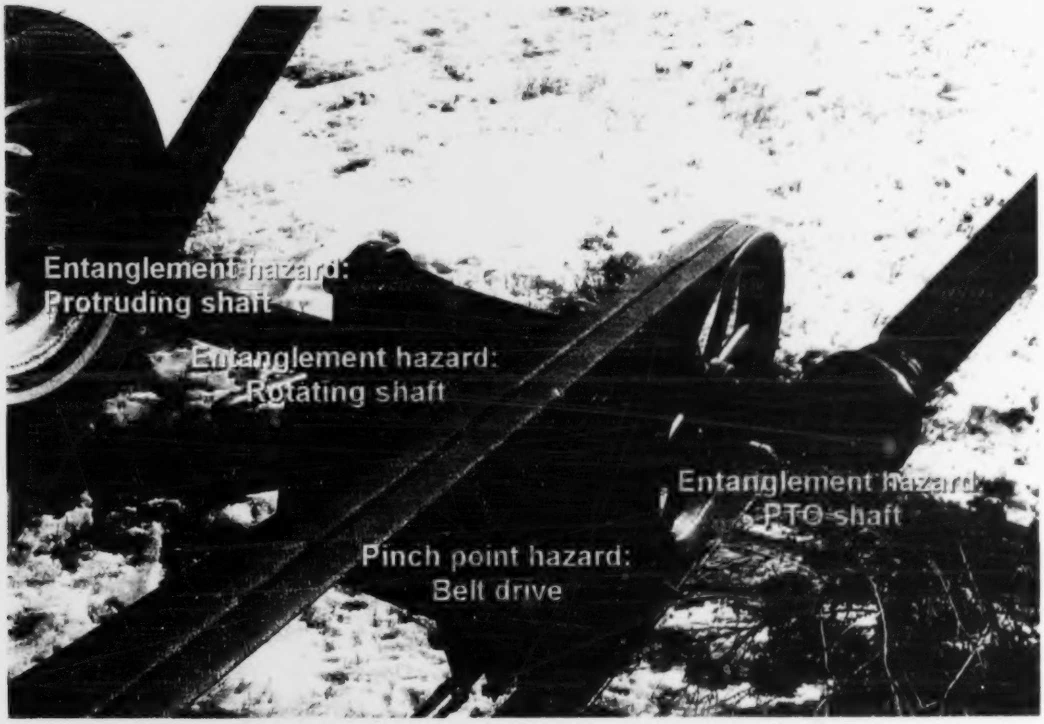

Entanglement hazard:
Protruding shaft
Entanglement hazard:
Rotating shaft
Entanglement hazard:
PTO shaft
Pinch point hazard:
Belt drive

Figure 28. Common Unguarded Hazards.

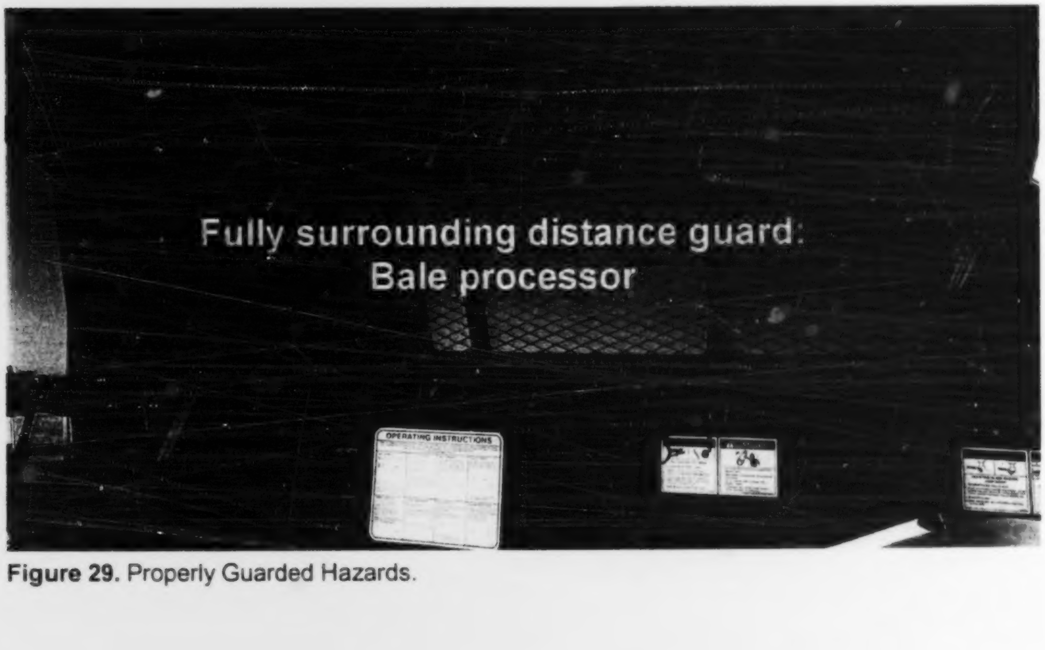

Fully surrounding distance guard:
Bale processor
OPERATING INSTRUCTIONS

Figure 29. Properly Guarded Hazards.

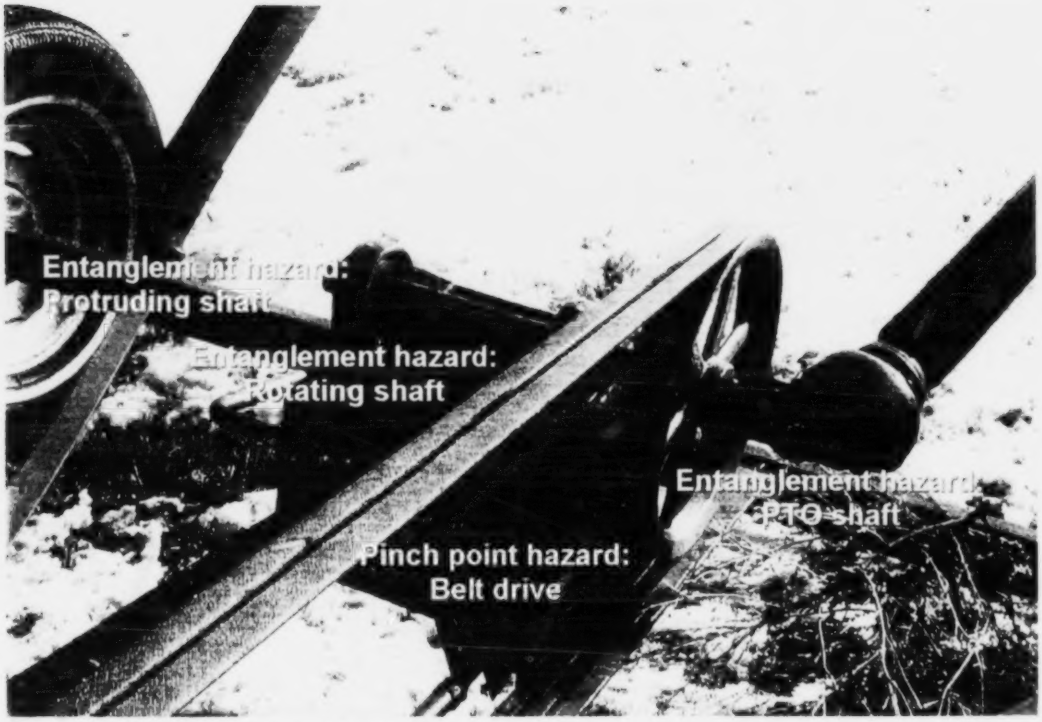

Entanglement hazard:
Protruding shaft
Entanglement hazard:
Rotating shaft
Entanglement hazard:
PTO shaft
Pinch point hazard:
Belt drive

Figure 28. Common Unguarded Hazards.

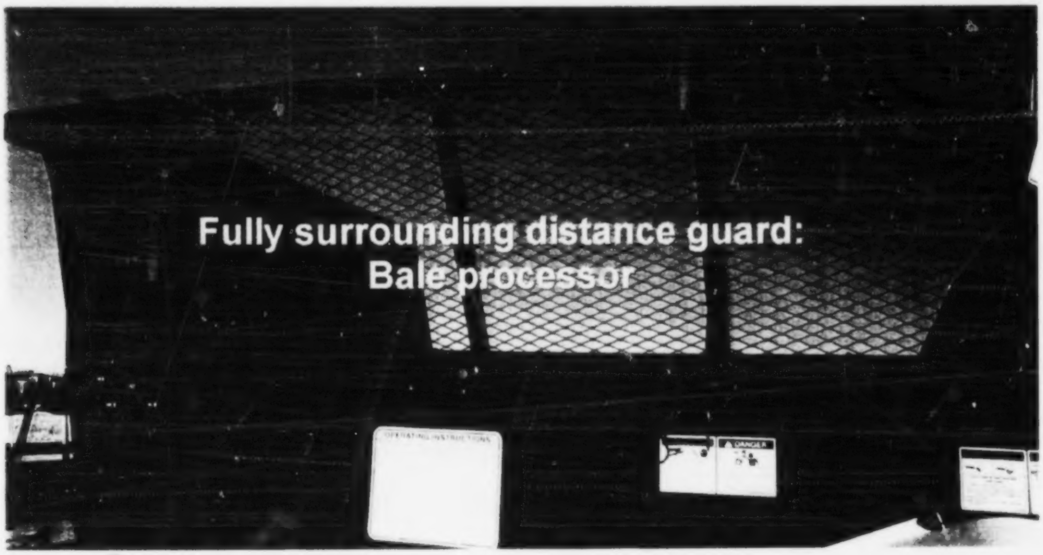

Fully surrounding distance guard:
Bale processor
OPERATING INSTRUCTIONS
DANGER

Figure 29. Properly Guarded Hazards.

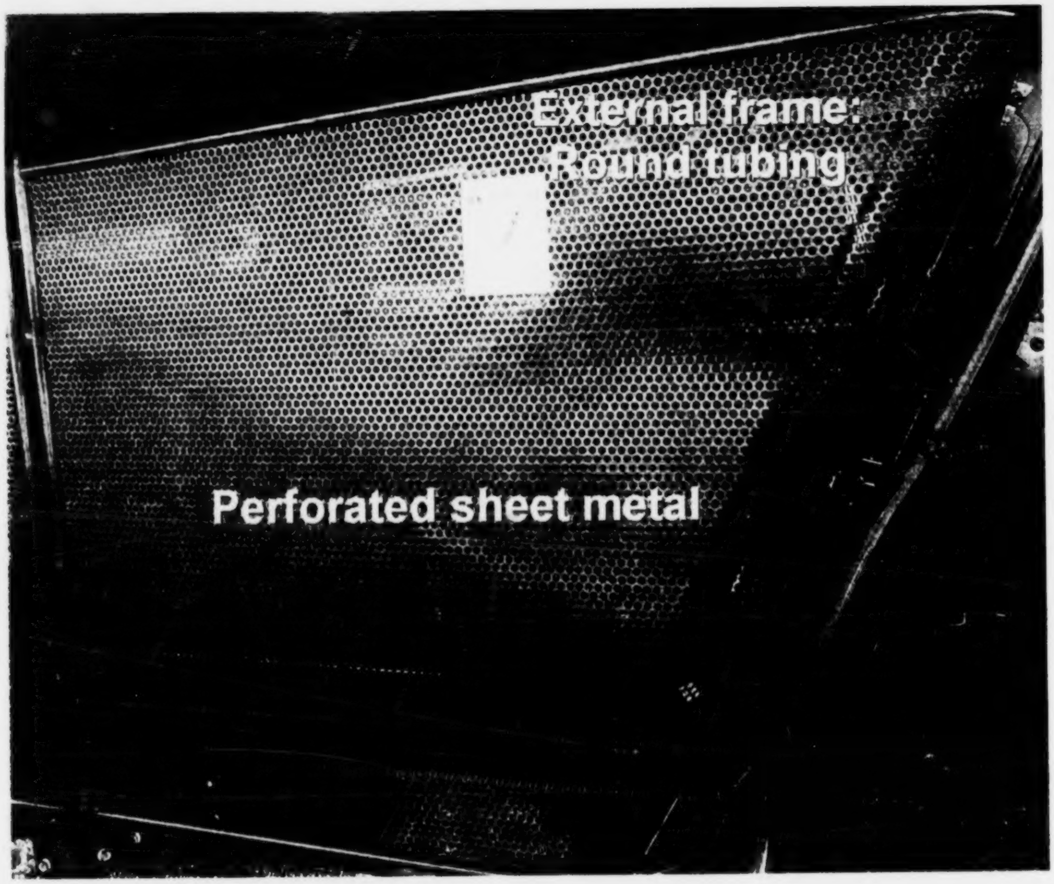

External frame:
Round tubing
Perforated sheet metal

Figure 30. Common Guarding Material.

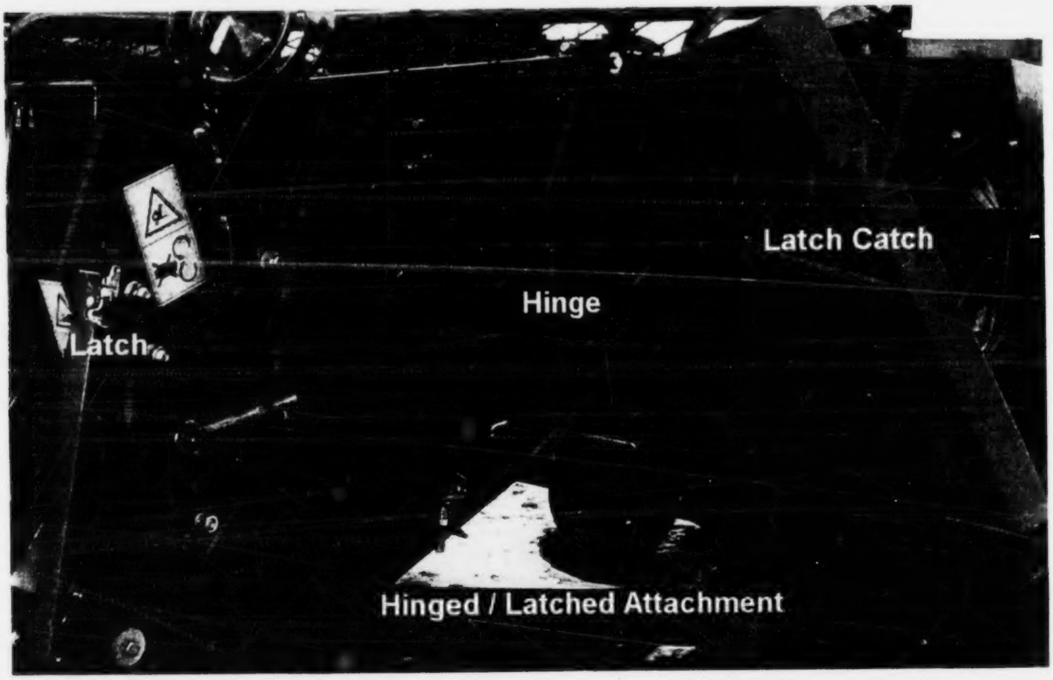

Latch Catch
Hinge
Latch
Hinged / Latched Attachment

Figure 31. Typical Hinged Guard System.

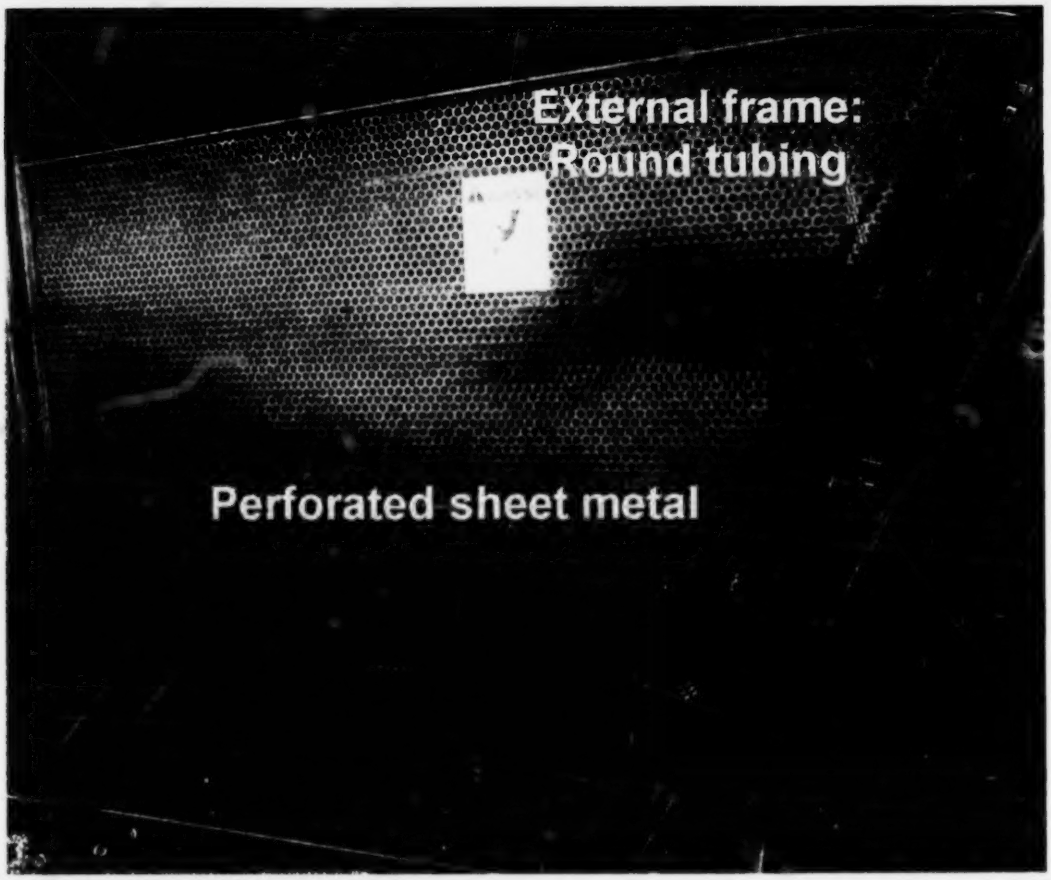

External frame:
Round tubing
Perforated sheet metal

Figure 30. Common Guarding Material.

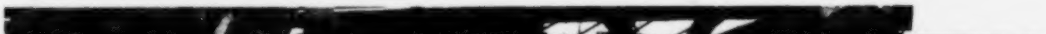

Latch Catch
Hinge
Latch
Hinged / Latched Attachment

Figure 31. Typical Hinged Guard System.

In summary, the *On Guard* manual was developed as an easy-to-use interpretation of Engineering Guarding Standards that allows producers to easily and economically make their own guards for used equipment that may not be properly guarded. The manual is currently receiving final review by many agencies from across Canada. A complete copy of the current manual is in **Section 5.**

2.3.4 Technology Transfer

During the project, a television interview was conducted at CTV Yorkton and an article was written in CanFarmSafe.

After completion of the "Develop and Test" phase, alternatives were considered for the most effective means of technology transfer. It was decided to do some planning to determine a "starter" list of options.

For example, some of the options on the auger inlet project were:

- Patent and sell license to a manufacturer.
- Patent and have PAMI manufacture and sell the units.
- Not to patent and generally release the design to the agricultural community at large without any fees assigned.

In keeping with the theme that we wanted this technology to be put in the hands of the end users as quickly and easily as possible, option #3 was selected. Adequate information was released so that farmers could build their own units if they wished. In addition, if manufacturers of augers or add-on auger components wanted to manufacture the guard, they would be able to proceed. They would not be obliged to utilize all specifics of the design but rather to adopt any of the concepts or specifics that they wished and also be free to adapt the design to their own manufacturing process or marketing system. To further keep this design as accessible as possible, by PAMI publicizing their discovery to the public and then choosing not to patent, this becomes "un-patentable" and open to the public domain. This ensures it will remain available to the public at large without cost. This approach is also used by at least some of the manufacturers already whenever they develop a new safety technology.

The approach with the *On Guard* manual was to make some sample draft copies available and to distribute these to as many groups as possible for their review and comments.

A cross-Canada tour was made where each of the agricultural safety organizations/individuals in each of the 10 provinces was visited to determine the best way to apply these two technologies to their requirements. A Power point presentation was prepared. Also, a model of the "Star" guard and draft copies of *On Guard* were taken along. Meetings with two or three representatives from each province occurred in the following locations:

- Langely, BC
- Edmonton, AB
- Saskatoon, SK
- Portage la Prairie, MB
- Guelph, ON
- Montreal, QC
- Truro, NS
- Fredricton, NB
- Charlottetown, PE
- St. John's, NL

In Saskatchewan, presentations were made to members of the Institute for Agriculture Rural and Environmental Health and the Saskatchewan Alliance for Agricultural Health and Safety.

A summary of the resulting suggestions are listed below:

For the "Star" guard:

- Have drawings available for farmers to build their own.
- Support demonstration and promotion of some models.
- Encourage manufacturers to build some of the guards.

For the On Guard manual:
- Potential Users are:
    - Ag Safety Delivery Agencies
        - Provincial & National
    - Producers
    - Manufacturers
    - Dealers
    - Regulators
    - Standards Committees
    - Students – Shop Projects

- Optional delivery mediums are:
    - Pamphlets
    - CDs
    - Web
    - Can Wide Press Release
    - Can Ag Safety Week
    - TV Agricultural Shows

The technology transfer tour was an extremely useful method of ensuring that specific provincial requirements were understood to ensure all initiatives were as effective as possible.

2.3.5 Project Evaluation

The project stakeholders and participants were surveyed to determine the value and effectiveness of the project. The Evaluation form included the following questions:

1. Are injuries caused by auger inlets an issue in your province? (If No, skip to #3)
2. Do you think the "Star" guard and "Quick Move Collar" would help reduce auger inlet injuries in your province?
3. Are injuries caused by unguarded equipment an issue in your province? (If No, skip to #5)
4. Do you think the *On Guard* manual would help reduce injuries?
5. Do you think this project was worthwhile and that work should continue on applying engineering to reduce injuries from used/older agricultural equipment?
6. List any equipment safety issues that you would like to see being worked on.

The results as graphed can be seen in **Figure 32**.

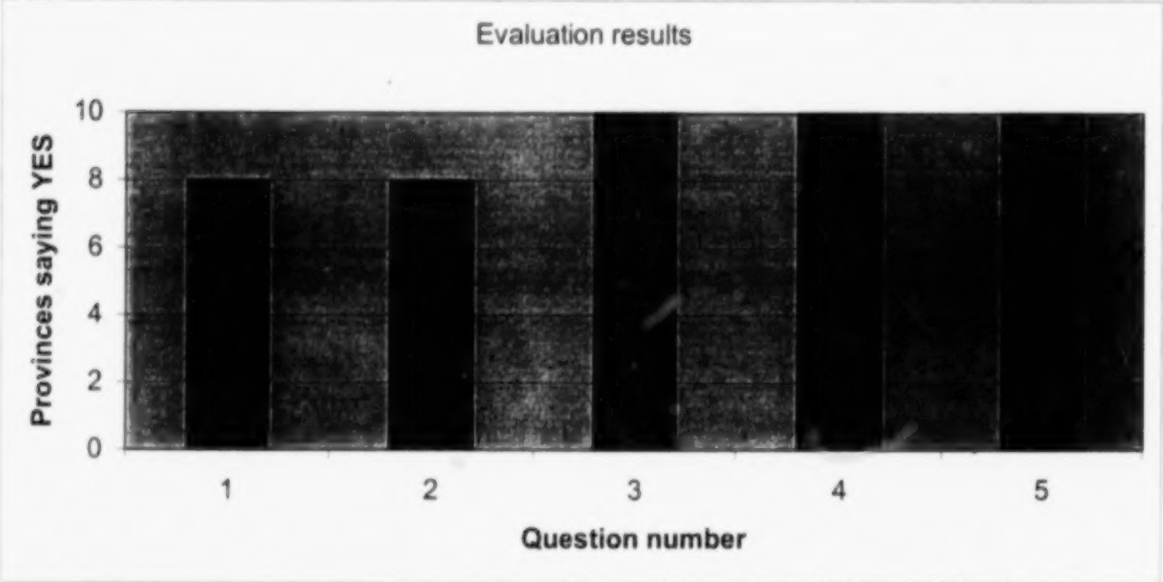


Figure 32. Evaluation Survey Results.

Auger intake injuries were a concern in eight out of the ten provinces. In all eight where auger injuries were an issue, it was felt the "Quick Move Collar" and "Star" guard would decrease injuries. Saskatchewan was one of the eight that felt auger injuries were an issue and that the developed guard would prevent injuries. Unguarded equipment was an issue in ten out of ten provinces. All ten provinces thought that the *On Guard* manual would help reduce injuries.

Also 100% of the respondents including those from Saskatchewan thought the project was worthwhile and that applying engineering solutions to reduce injuries dealing with used or old agricultural equipment should be continued.

Comments from the Evaluation Survey are shown in **Appendix II.**

2.3.6 Administration

This report and the *On Guard* manual are being translated into French and this is scheduled to be complete by the end of March 2004. The Saskatchewan Government translation service is translating *On Guard*. Hubert Landry, an Agricultural Engineering PhD candidate at the University of Saskatchewan who was born and raised in Quebec, is translating this report.

An independent financial audit is being conducted for CARD by the firm of Meyers Norris Penny and is scheduled for April 1 and 2, 2004

2.4 Conclusion and Recommendations

2.4.1 Auger Intake Guard

The "Quick Move Collar" guard is an excellent innovation that allows easy movement of an auger inlet guard while keeping the unit attached to the auger. The "Star" guard was found to be the best guard in terms of reduced plugging. It complied with the current standard and was an improvement over the current guards that new augers come supplied with.

2.4.2 Guarding Manual

The guarding manual is a useful tool in educating producers on how to improve the safety of their equipment. If utilized, it should help play a role in the reduction of agricultural machinery entanglement injuries.

2.4.3 CASA-ACSA Value

This project benefited greatly from the existing CASA-ACSA network. Firstly, it fostered the "seed" of this project as the project need was realized after several years of immersion in the CASA network of research data, individuals, and organizations. When the project required advisors, there was a readily available network of "experts" to call on. There was also a wealth of valuable research in existence to help focus and speed the project along. After the technologies were developed, the CASA group of lead agencies was the obvious mechanism to carry out the technology transfer. Without the existence of CASA, this project would have taken 2 – 3 times as long, probably have cost 2 – 3 times more, and most importantly it would not have been nearly as effective.

2.4.4 Recommendation

This project moved forward two very important initiatives to reduce injuries from used agricultural machinery. Based on the evaluation, it was felt that this project was beneficial and should be continued as a long-term initiative. There are many other hazards on used agricultural machinery that need to be addressed. These include retrofitting used tractors with ROPS and seatbelts, addressing the hazards involved with PTOs, and many other improvements to agricultural machinery safety.

4. Equipment

No equipment was purchased for this project. Use of the following PAMI equipment was provided as an In-Kind contribution:

- Crops Processing Development Centre
- Grain Truck
- Scale, Indicator, and Data Acquisition Equipment
- Telehandler
- Small Hoppered Bin
- Grain Auger

5. Project Developed Material

The *On Guard* manual (**Appendix IV**) was developed and is currently under the review of professionals and regulators from across the country.

6. Photos

Project photos have been included in **Section 2**, **Technical Report**.

8. ICAR Data Entry

This project has been entered into the Inventory of Canadian Agri-Food Research (ICAR) database. The associated ICAR reference number is 33331364.

APPENDIX I

Appendix I

Advisory Group

Name	Profession	Location	E-mail
Billy Woods	Producer & Farm Safety Professional	NL	billyw@roadrunner.nf.net
Bob Ross	Regulator	SK	bross@lab.gov.sk.ca
Bruce Johnson	Farm Safety Professional	BC	Agriculturalsafe@farsha.bc.ca
Cameron Bodie	Manufacturer & Engineer	SK	cbodie@brandt.ca
Carl Palmer	Farm Safety Professional	PEI	carl.palmer@ns.sympatico.ca
Cathy Vanstone	Farm Safety Professional	MB	cvanstone@gov.mb.ca
Charles Everett	Agricultural Professional	NB	chuck.everett@gnb.ca
Curtis Evenson	Producer	MB	cevenson@mts.net
Dave Shanahan	Standards Committee	ON	dave.shanahan@csa.ca
Dean Anderson	Farm Safety Professional	ON	danderson@Agriculturalsafety.ca
Dean Rathwell	Agricultural Professional	SK	dean.rathwell@fcc-fac.ca
Deborah Ehmann	Producer & Farm Safety Professional	SK	casa-acsa@usask.ca
Deborah Guiillemett	Agriculture Professional	NL	fed.agric@nf.sympatico.ca
Doina Priscu	Regulator & Engineer	MB	dpriscu@gov.mb.ca
Don Anderson	Farm Safety Professional	PEI	slandpei@attcanada.ca
Douglas Durant	Manufacturer & Standards Committee & Engineer	USA	durantdouglasm@johndeere.com
Elizabeth Crouse	Farm Safety Professional	NS	crouseea@gov.ns.ca
Finbar Desir	Regulator & Engineer & Standards Committee	ON	fdesir@omafra.gov.on.ca
Gary Mawhiney	Agricultural Professional	ON	gary.mawhiney@omaf.gov.on.ca
Genevieve Pickett	Agricultural Professional	CN	picketg@em.agr.ca
Glen Blahey	Farm Safety Professional	MB	GBlahey@gov.mb.ca

Gordon Bryant	Agricultural Professional	BC	gordon.bryant@gems3.gov.bc.ca
Helen McDuffie	Medical Professional	SK	mcduffie@skyway.usask.ca
James Dosman	Medical Professional	SK	James.Dosman@usask.ca
Judy Guernsey	Medical Professional	NS	judy.guernsey@dal.ca
Julie Bidwell	Medical Professional	SK	bidwellj@sask.usask.ca
Ken Imhoff	Agricultural Professional	SK	kimhoff@agr.gov.sk:ca
Kieran Green	Agricultural Professional	CN	kieran@cfafca.ca
Larry Campbell	Producer	BC	lc@campbellco.ca
Larry Nason	Producer	NB	lmn@nb.sympatico.ca
Laurel Aitken	Farm Safety Professional	AB	laurel.aitken@gov.ab.ca
Lawrence Manchur	Standards Committee & Engineer	MB	lmanchur@gov.mb.ca
Lloyd Evans	Agricultural Professional	NS	lsevans@glinx.com
Lorne Henry	Standards Committee & Producer	MB	
Lucie Lacasse	Agricultural Professional	QC	llacasse@upa.qc.ca
Marilyn Affleck	Farm Safety Professional	PEI	marilyna@peifa.ca
Martine Mercier	Farm Safety Professional	QC	mmercier@upa.qc.ca
Maurice Korol	Agricultural Professional & Standards Committee	CN	korolma@em.agr.ca
Nicole Arseneau-Ruttan	Farm Safety Professional	NB	nicole@nbAgricultural.com
Rick Atkins	Engineer	AB	rick.atkins@gov.ab.ca
Rob Brison	Medical Professional	ON	brisonr@kgh.kari.net
Rod Scarlett	Agricultural Professional	AB	wrap@planet.eon.net
Roger Hoy	Engineer & Manufacturer	USA	hoyrogerm@johndeere.com
Roland Kilpatrick	Standards Committee & Engineer	ON	roland.kilpatrick@nrc.ca
Sharon Clark	Medical Professional	SK	sharon.clark@shr.sk.ca
Steve Zronik	Farm Safety Professional	ON	szronik@Agriculturalsafety.ca

Ted Whitworth	Farm Safety Professional & Standards Committee & Producer	ON	twhitworth@Agriculturalsafety.ca
Will Pickett	Medical Professional	ON	pickettw@kgn.kari.net
Trever Crowe	Engineer	SK	trever.crowe@usask.ca
Yves Brissette	Regulator	QC	Yves.Brissette@csst.qc.ca

APPENDIX II

Appendix II

Project Evaluation Comments

Comments about the auger intake guard modification included:

- Agree that the intake end is the most hazardous area of an auger.
- Moveable guards should not cause problems during operation.
- Its effectiveness depends on its use.
- It seems easy to use, and most likely would not be removed once installed.
- The mini-model was excellent for visual learners.

Comments about the *On Guard* manual included:

- Entanglement injuries are a common problem, especially in PTOs.
- It provides common sense solutions to everyday problems.
- It increases awareness.
- It must get out to the farmers.
- CASA should lead a national printing of the manual.

Comments about the effectiveness of the overall project included:

- It is the first document that has information that makes sense and would help farmers to make changes that are inexpensive.
- Many farmers do not make safety a high priority, removing the hazard removes the onus on farmers to protect them.
- Economically "used" equipment will continue to be used on farms.
- The concept of National Input was excellent.

Comments about safety issues that should be studied include:

- PTO entanglements (3).
- Tractor rollover protective structures (ROPS) (3).
- ROPS on used tractors (even if some say it cannot be done).
- Unprotected pulleys.
- Access steps to equipment.
- Catwalks on high equipment.
- Equipment that require laborers riding on machinery during use such as potato harvesters.
- “Trainee” seat safety.
- Should ask farmers directly.
- Barn redesign to address “milkers knee” and back problems.

APPENDIX III

Appendix III

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APPENDIX IV

Appendix IV

On Guard Manual

ON GUARD!

X
DANGER
✓
DANGER
WARNING

DRAFT COPY

Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada

Saskatchewan Agriculture, Food and Rural Revitalization

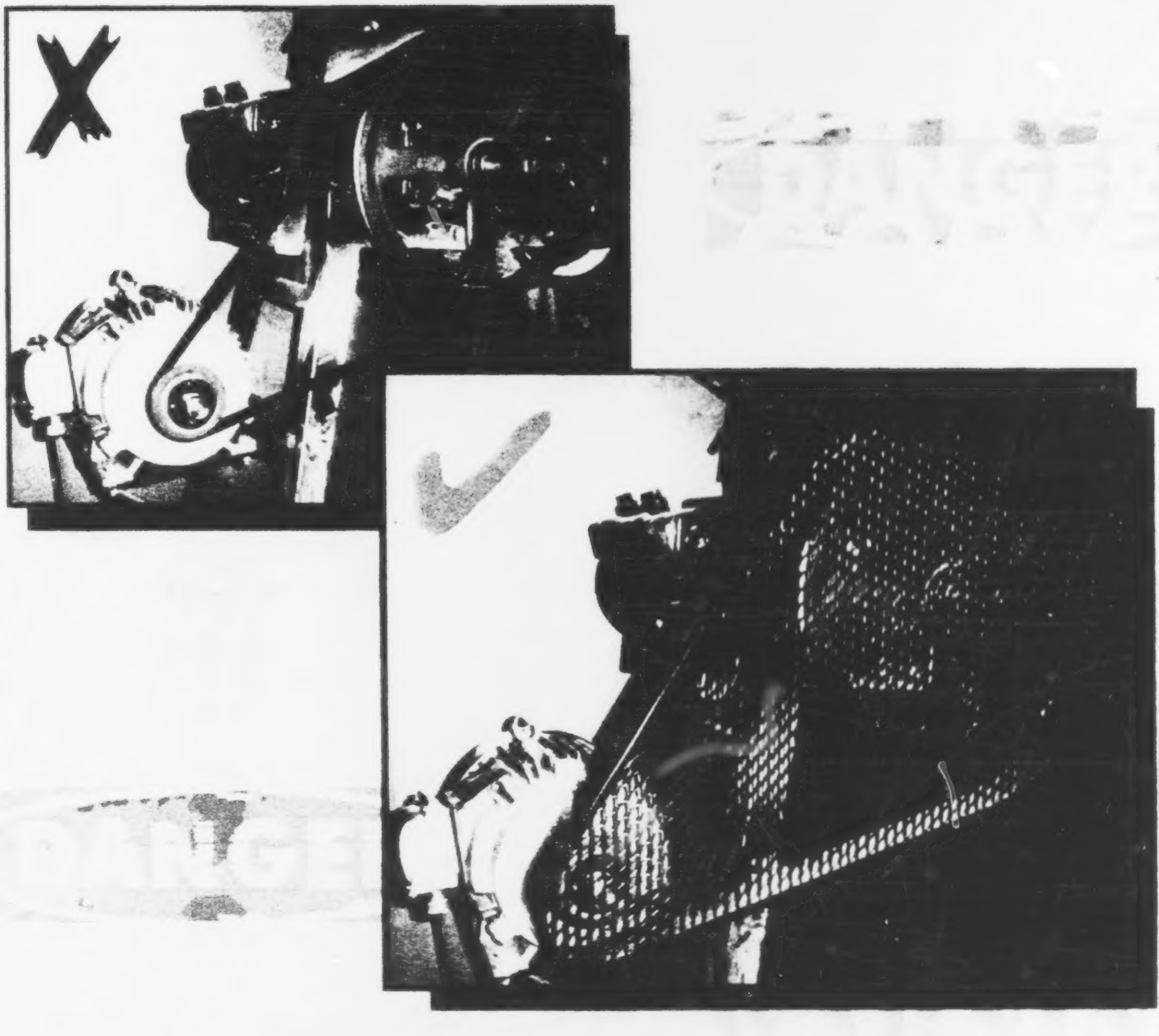
BOURGAULT

PAMI

Agtech Centre

ON GUARD!

A Handbook for [illegible] Farm Equipment



Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada

Saskatchewan Agriculture, Food and Rural Revitalization

BOURGAULT

PAMI

Agtech

Farm Machinery Guarding Procedure

Step 1: Risk Assessment
What is the Function of the Machine?
What Hazards Exist?
Risk Estimation
Risk Evaluation

Step 2: Guard Type Selection

Step 3: Guard Design, Fabrication, and Attachment
Guard Design
Guard Fabrication
Guard Attachment

Step 4: Is the Machine Safe?

Acknowledgements

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Agriculture and Agri-Food Canada
Saskatchewan Agriculture, Food and Rural Revitalization
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Bourgault Industries
Prairie Agricultural Machinery Institute (PAMI)

NOTE: ***The opinions expressed in this document are those of PAMI, and not necessarily the funders.***

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Hazard Symbol Glossary Inside Back Cover

1. Fast-Track User's Guide

The information in this handbook has been designed to help farm machinery owners and operators retrofit their used machinery with proper guarding. It does not replace or supersede any CSA, ASAE, OSHA, or ISO standards that are updated on a regular basis; nor is it a legal document to be used for law enforcement. Should you have any specific questions, your should consult with a Farm Safety Organization (see list of organizations on back cover of this publication), or other qualified people.

1.1 Introduction

Handbook Objective

This handbook was developed as a guide to assist and encourage farmers in the design and fabrication of guards for their farm machinery.

International standards organizations have established guarding requirements which are minimally acceptable and technically feasible for the safeguarding of new farm machinery. However, there are no standards dealing specifically with the guarding of used farm machinery. This guide aims to encourage farmers to safeguard their used machinery to adhere to the standards that govern new machinery.

Injury Statistics

There are over 1700 farm related, hospitalized injuries per year in Canada[1]. Farm machinery injuries cost the Canadian economy between $200 - $300 million annually[2]. Fatal injuries average cost was $275 000, permanent disability injuries average cost was $143 000, while the average cost of hospitalized injury was $10 000[2].

Over 850 of these injuries that are serious enough to be admitted to hospital are related to farm machinery. Almost one third of these injuries resulted from becoming entangled in the machinery. Most of these entanglement injuries could have been prevented if the machinery involved was guarded sufficiently. If this handbook prevents even one injury it has more than paid for the cost to develop and print it.

The injuries were caused by a combination of unguarded hazards and the person getting too close to the hazards.

PAMI Recommendation:
Always shut the engine or power off before servicing any part of machinery.

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Definitions

Guard: A physical barrier that prevents access to a danger zone.

Danger Zone: The zone around the machine (front, back, sides, top, and bottom) where a hazard is created by the motion of the machine components

Hazard: A situation that may cause injury to a person.

Machinery: Apparatus for producing or applying power, having fixed or moving parts each with definite functions. This includes powered and non-powered machinery such as pulled implements. The term machinery also includes stationary equipment such as seed processing machinery and livestock handling equipment.

1.2 What Should be Guarded?

The guarding guidelines in this handbook have been sourced from CSA, ASAE, OSHA, and ISO standards. They apply to new farm machinery. This handbook will use these standards to guide the farmer in the design and fabrication of guards for their used machinery.

What should be guarded?

- Nip-points such as belt drives, chain drives, and gears.
- Outside faces of pulleys, sheaves, sprockets and gears.
- Revolving shafts, universal joints, PTO shafts, and other revolving parts with projections such as exposed bolts, keys, pins, or setscrews.
- Surfaces which create shearing or pinching hazards such as auger inlets.
- Revolving engine components such as radiator fans.
- Ground-driven components, only if operating personnel are required to be in the area while the drives are in motion.
- Moving traction elements (wheels or tracks) in relation to the operator's station.
- Hot surfaces such as radiators.
- Live electrical components such as battery posts.

1.3 Farm Machinery Guarding Procedure

This procedure was developed to provide farmers with simple guidelines to identify hazards, and design and fabricate guards to eliminate the hazards on their farm machinery.

1.3.1 Risk Assessment

Do not spark your cutting torches and welders right away. It is possible to fabricate and install a guard and still not ensure the machine is safe. In order to ensure your machinery is safe, it is important to take a moment and ask a few questions.

Risk Assessment is a series of steps that machinery designers use to examine the hazards associated with a machine. You are essentially starting this process when you decide to design and fabricate your own guards. For a detailed explanation of Risk Assessment see **Section 2.2** of this guide. The following steps summarize Risk Assessment.

PAMI Recommendation:
For each machine owned, photocopy the form in **Appendix VII** to record each step of the farm machinery guarding procedure. The time required to complete this procedure could be well worth it if it prevents just one injury.

What is the Function of the Machine?
The first simple questions you should answer are: What is the machine used for? What motions or actions does it perform? Also consider any misuse the machine might see in its lifetime.

What Hazards Exist?
Hazard identification includes all hazards, hazardous situations, and hazardous events associated with the machinery. Listed below are examples of hazards that may be present:

- Impact
- Crushing
- Stabbing and puncture
- Friction and abrasion
- Heat
- Electrical
- Compressed air or high-pressure fluid injection
- Entanglement
- Drawing-in
- Pinch points
- Thrown objects
- Cutting
- Shear

See **Section 2.3** of this guide for detailed explanations of these hazards. The following pictures show some common areas where these hazards exist. (**Figures 1, 2, 3, 4, and 5**)

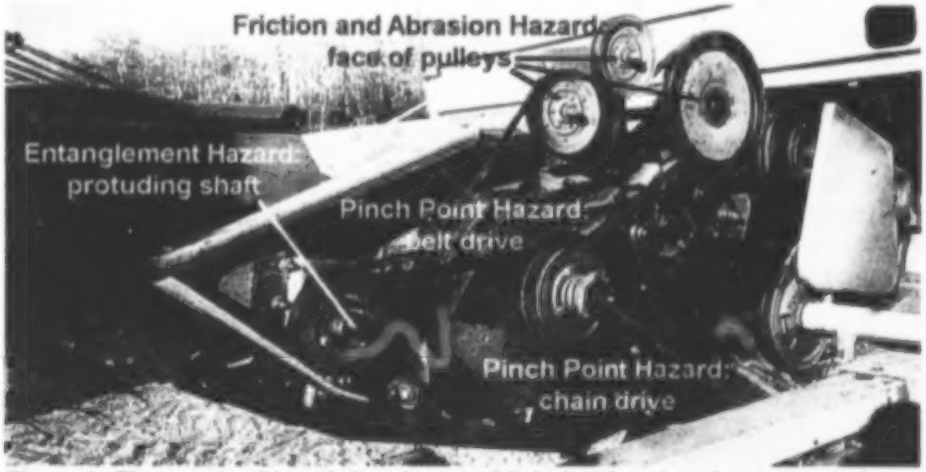
Friction and Abrasion Hazard: face of pulleys
Entanglement Hazard: protuding shaft
Pinch Point Hazard: belt drive
Pinch Point Hazard: chain drive

Figure 1. *The guards of drive belts, chains, and shafts of combine headers are often removed for service access and are not replaced.*

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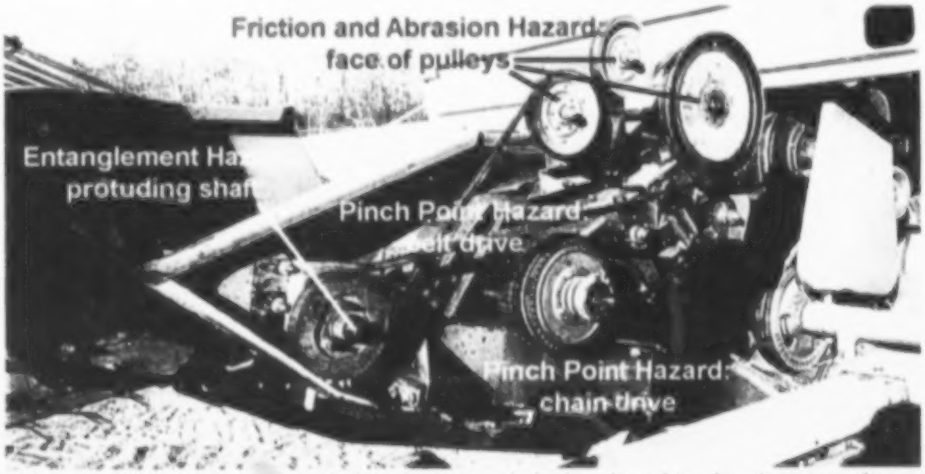

Figure 1. *The guards of drive belts, chains, and shafts of combine headers are often removed for service access and are not replaced.*

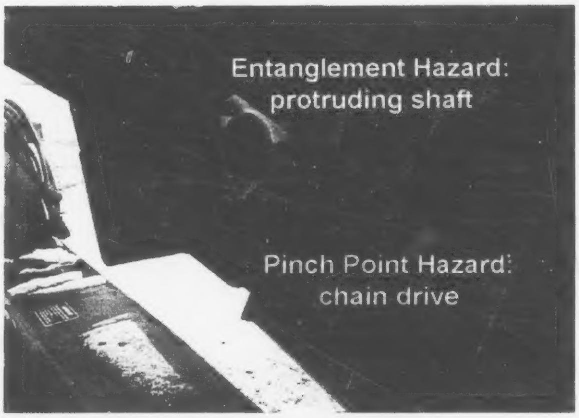
Entanglement Hazard:
protruding shaft
Pinch Point Hazard:
chain drive

Figure 2. *Protruding shafts and chain drives are common hazards found on combine pickups.*

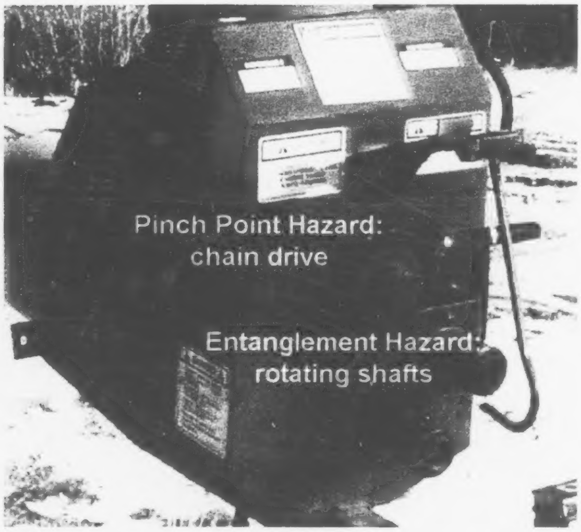
Pinch Point Hazard:
chain drive
Entanglement Hazard:
rotating shafts

Figure 3. *Chains, belts, and shaft drives are common hazards found on augers.*

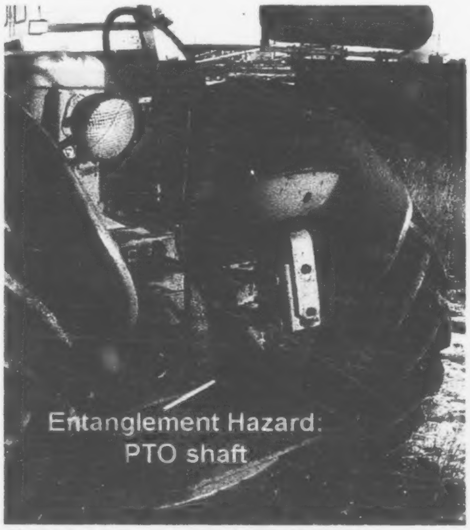
Entanglement Hazard:
PTO shaft

Figure 4. *Guards for PTO shafts are commonly removed and not replaced.*

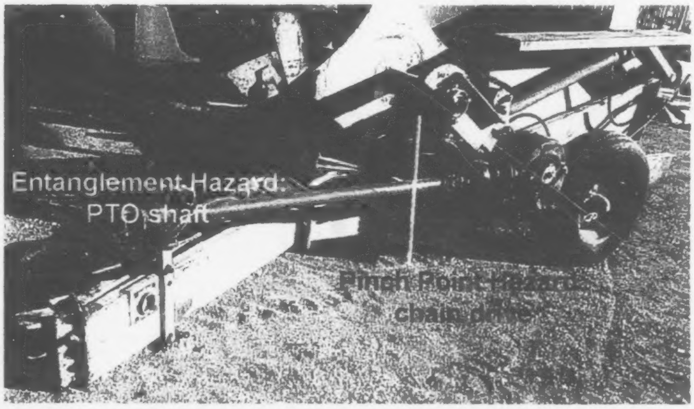
Entanglement Hazard:
PTO shaft
Pinch Point Hazard:
chain drive

Figure 5. *PTO driven machinery like this rock picker have potentially fatal hazards if left unguarded.*

Risk Estimation

For each hazard identified, it is important to answer the following questions:

- What is the severity of possible injury?
- What is the probability of the injury occurring?

Total risk is the severity multiplied by the probability. The high-risk hazards should be safeguarded first. See **Section 2.2.3** of this guide for detailed explanations of these terms.

Risk Evaluation

Risk evaluation determines whether risk reduction is required or if safety has been achieved. If risk reduction is required then the following question should be asked:

- Will guarding reduce the risk?

Keep in mind not all hazards can be eliminated by guarding. Other forms of safeguarding not covered in this handbook may be required.

STATISTIC: *In Canada, there is an average of 10 fatalities per year caused by entanglement in agricultural machinery. This accounts for 10% of all agricultural machinery related fatalities.*[3]

PAMI Recommendation:

Before you start building a guard, there may be alternatives:

1. Purchase a new guard from a dealer... if there was an original one that was removed.
2. Purchase a used guard from a machinery wrecker...if there was an original that was removed.
3. Repair the existing guard...if it was removed due to damage.

1.3.2 Guard Type Selection

After risk assessment has been completed and it has been determined that guarding will reduce risk, guard selection can begin. Agriculture equipment dealers may be able to supply the proper guard. In many provinces, dealers are required to provide all replacement parts for a machine for 10 years after its production has ended. If your machine is older than this 10-year period, salvage yards may have the proper guard. If these sources are unsuccessful put on your safety glasses and continue on with this guide.

There are two types of guards:

- Fixed
- Movable

There are four classifications of guards:

- Local enclosing
- Fully enclosing
- Local distance
- Fully-surrounding distance guard

Section 2.4.2 provides further information on guard types and classifications. See **Appendix III** for a Guard Type Selection Flowchart.

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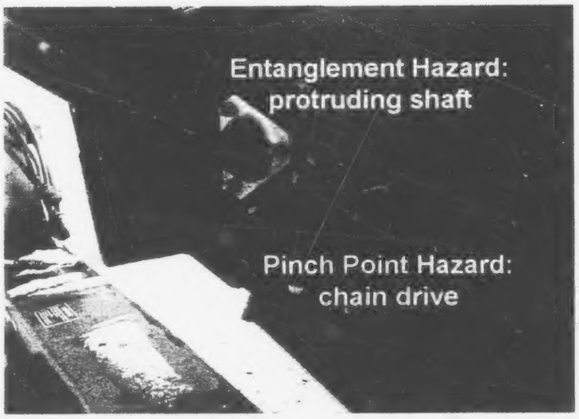
[3] Canadian Agricultural Injury Surveillance Program (CAISP). Agricultural Injuries in Canada for 1990 - 2000. 2003.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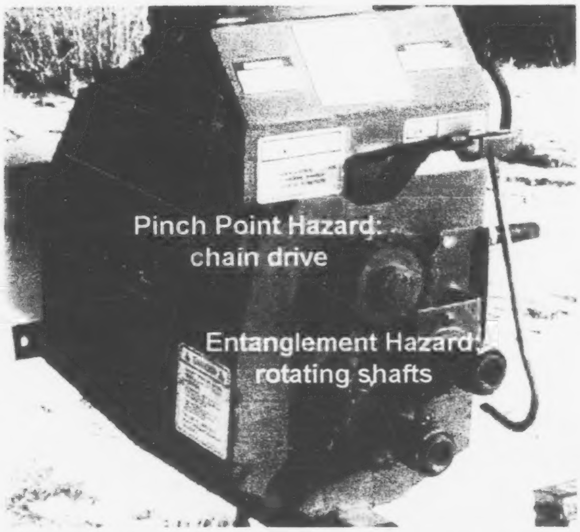
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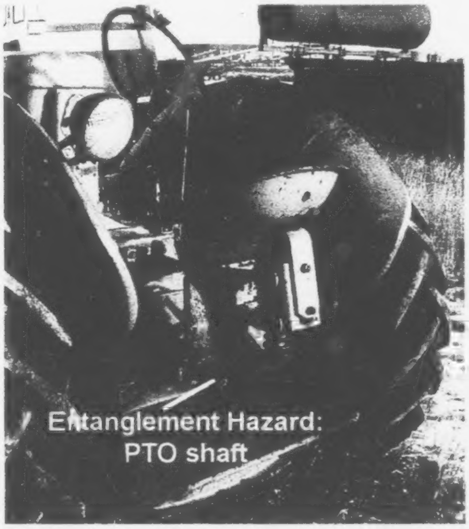
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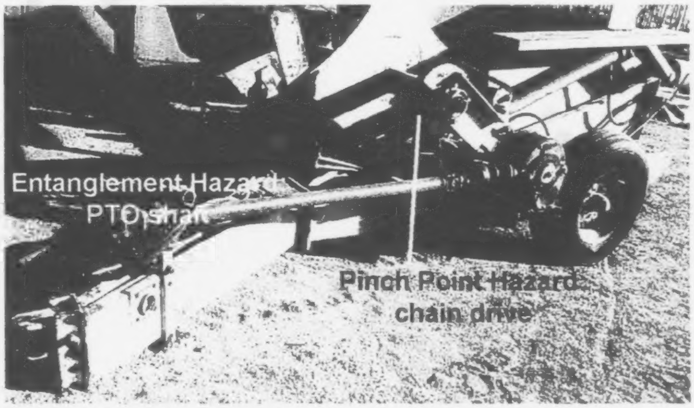
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1.3.3 Guard Design, Fabrication, and Attachment

Guard Design

Proper guard design involves the following considerations. **Sections 2.4.3 and 2.4.4** give more detail on the considerations and design criteria for guards.

- Consider frequency of access required to the hazard.
- Is viewing of the guarded process or components required?
- Consider the size and weight.
- Ensure durability.
- The moving guard parts should be reliable.
- The guard should have sufficient impact resistance.
- Ensure no crushing or trapping points are created.
- Ensure there are no sharp edges created.
- The guard should be securely fixed to the machine.
- Warning decals should be applied.
- The guard should be resistant to corrosion.
- Appropriate guard colors should be used.
- Consider proper guard attachment methods.
- Safety Distances: Simply ensure that fingers or hands can't reach far enough through, around, along, or over the guard or barrier to access the hazard.

PAMI Recommendation:
Visit dealer lots, auctions, or other farmers to view similar machines to get ideas for guard design.

Guard Fabrication

PAMI Recommendation:
Be sure to use personal protection equipment like face shields and welding gloves during fabrication.

Material selection is the first fabrication step. Metal is the most common material used in guards for farm machinery. It is readily available, low cost, and durable. See **Section 2.4.5** for specific material recommendations.

- If a shield or enclosure is to be fabricated, using sheet steel with thin wall round tubing reinforcement is a common approach. This steel sheet could either be solid sheet metal, expanded mesh, or perforated sheet metal. Viewing of the hazard through the guard is easier if expanded mesh or perforated sheet metal is used.
- Where distance barriers are used, material such as round pipe and square tubing can be used.
- Use cardboard, duct tape, and a utility knife to acquire the basic dimensions for the guard. This could reduce wasted time and material in the end.

- After the basic dimensions are found, fabricate the external structural frame.
- Attach any required sheet metal, perforated metal, or expanded mesh walls next.
- After guard fabrication is complete be sure to paint the guard to prevent corrosion and affix safety decals to enhance hazard awareness. **Appendix V** includes a safety decal guide.

PAMI Recommendation:
Where hinged or removable guards expose dangerous parts (e.g. rotating shafts) paint the inside of the guards a bright distinguishing color. If it is not practical to apply the distinguishing color to the guard, then paint the dangerous items themselves. (Examples include: ends of shafts, rims of pulleys, edges of blades, sides of belts or chains, sides of sprockets, and sides of gears) This will give attention to any guard that has been removed and not replaced.

Guard Attachment

The guard attachment should be secure so it does not create any additional hazards. If a guard is difficult to detach then it will likely not be reattached. The most important consideration is the frequency of access to the hazard. If the hazard is accessed frequently for machine adjustment or service then a moveable guard should be used. If a hazard is seldom accessed (example: once per year of operation) then a fixed guard will provide the most durable and secure attachment. A fixed guard should still be easily removed with common hand tools. For further explanation and examples of the following attachment methods see **Section 2.4.4**:

- Bolted (fixed)
- Hinged / Latched (moveable)
- Hinged / Pinned (moveable)
- Dowels / Pinned (moveable)
- Sliding / Pinned (moveable)
- Slot and Tab / Pinned (moveable)

PAMI Recommendation:
Refer to **Appendix VI** for a guide on guard attachment components.

1.3.4 Is the Machine Safe?

After completing the process and affixing guards, this question should be asked to ensure there haven't been any additional hazards created. If it is determined that the machine still is not considered safe, then continue the process until safety is achieved.

PAMI Recommendation:
If you are having trouble finding a parts supplier for an uncommon brand of machinery, you may find these websites useful:
- www.cweda.ca (Canada West Equipment Dealers Association)
    - go to Links, then Obsolete/Hard to Find Parts
- www.orfeda.com (Ontario Retail Farm Equipment Dealers' Association)

1.3.3 Guard Design, Fabrication, and Attachment

Guard Design

Proper guard design involves the following considerations. **Sections 2.4.3 and 2.4.4** give more detail on the considerations and design criteria for guards.

- Consider frequency of access required to the hazard.
- Is viewing of the guarded process or components required?
- Consider the size and weight.
- Ensure durability.
- The moving guard parts should be reliable.
- The guard should have sufficient impact resistance.
- Ensure no crushing or trapping points are created.
- Ensure there are no sharp edges created.
- The guard should be securely fixed to the machine.
- Warning decals should be applied.
- The guard should be resistant to corrosion.
- Appropriate guard colors should be used.
- Consider proper guard attachment methods.
- Safety Distances: Simply ensure that fingers or hands can't reach far enough through, around, along, or over the guard or barrier to access the hazard.

PAMI Recommendation:
Visit dealer lots, auctions, or other farmers to view similar machines to get ideas for guard design.

Guard Fabrication

PAMI Recommendation:
Be sure to use personal protection equipment like face shields and welding gloves during fabrication.

Material selection is the first fabrication step. Metal is the most common material used in guards for farm machinery. It is readily available, low cost, and durable. See **Section 2.4.5** for specific material recommendations.

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2. Detailed User's Guide

2.1 Introduction

Guarding Standards

The majority of information for this handbook was gathered from the following standards organizations:

- CSA (Canadian Standards Association)
- ASAE (American Society of Agricultural Engineers)
- ISO (International Standards Organization)
- OSHA (U.S. Department of Labor / Occupational Safety and Health Administration)

See **Appendix I** for the specific standards and how to order them.

Prairie Agricultural Machinery Institute (PAMI)

PAMI is working in cooperation with Canadian Adaptation and Rural Development (CARD); Saskatchewan Agriculture, Food and Rural Revitalization; the Agriculture Development Fund (ADF); the Alberta AgTech Centre (ATC); and Bourgault Industries to deliver the **"On Guard!"** safety message to Canadian farm machinery owners and operators.

PAMI recommendations throughout this handbook note additional guarding suggestions, which may or may not be mentioned by standards organizations.

PAMI Recommendation:
Refer to **Appendix II** at the back of this book for a handy glossary of terms.

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PAMI Recommendation:
Refer to Appendix II at the back of this book for a handy glossary of terms.

2.2 Risk Assessment

Risk assessment is done to determine the level of safety precautions necessary. All agricultural machine designers use this process to answer the question: Is the machine safe?

2.2.1 What are the limits of the machine?

The "limits of the machine" is simply its intended use. It is important to consider the purpose or function of the machine. This will help in the identification of hazards. Also consider any foreseeable misuse of the machine. The implementation of guarding should not inhibit the machines function.

2.2.2 Hazard Identification

What hazards are present? Just as important as the fabrication of the guard is the identification of the hazards to be guarded. Some hazards may appear obvious, but some may not be recognized as dangerous. See **Section 2.3** for examples of the hazards present in farm machinery.

2.2.3 Risk Estimation

Two factors of risk should be taken into account:

- **The Degree or Severity of Foreseeable Injury**

  Consider:

  - What type of mechanical or other hazard is involved?
  - What types of injuries can be foreseen?
  - What loss to the individual, the individual's family, the employer, and the community does each possible degree of injury represent?

- **The Probability of the Injury Occurring?**

  Consider:

  - The frequency of access to or beyond a danger point during each phase of machine life (machine operation, breakdown, commissioning, maintenance, setting, and process changeover).
  - The proportion of each type of access likely to cause injury.
  - The absence of injury from machinery used without safeguards over a period of time does not mean that the machine is completely safe.

2.2.4 Risk Evaluation

Risk evaluation determines what safeguards are required for risk reduction. Even after all hazards have been guarded, it is important to consider any remaining risks associated with operating the machine. Many times it is not possible to guard against all potential hazards. The operator manual and safety decals should provide guidance on additional hazards.

STATISTIC: *Entanglement in a rotating PTO or drive shaft is the leading mechanism of entanglement fatalities accounting for 44% of all cases in Canada.*[4]

---

[4] CAISP. 2003.

2.3 Types of Hazards

Entanglement

Entanglement occurs as a result of bodily contact with one of the following features:

- A single rotating surface
- Projections or gaps
- Counter rotating parts
- Rotating and tangentially moving parts
- Rotating and moving parts
- Rotating and fixed parts
- Material in motion

(**Figures 6, 7, 9, and 16**)

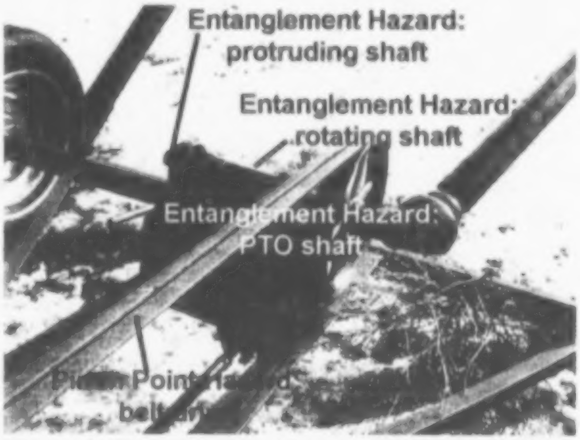
Entanglement Hazard: protruding shaft
Entanglement Hazard: rotating shaft
Entanglement Hazard: PTO shaft
Pinch Point Hazard: belt drive

Figure 6. *This PTO auger has multiple hazards associated with it.*

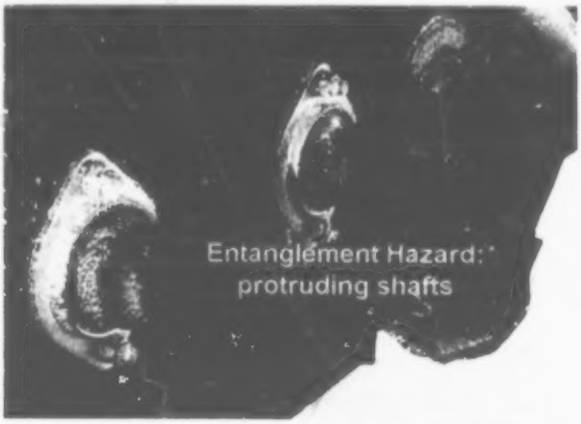
Entanglement Hazard: protruding shafts

Figure 7. *Protruding shafts with keyways are potential entanglement hazards.*

PAMI Recommendation:
Smooth shafts with no projections are not necessarily safe. Cut shafts and spindles off flush with bearings, sprockets, or pulleys wherever possible. If this is not possible, enclose the protruding shaft in a fixed-sleeve or cap-type guard constructed of suitable material, such as sheet metal. Plastic shaft-end caps are commonly used on new equipment and can be purchased at most agricultural dealerships.

Drawing-In

Drawing in occurs as the result of bodily contact with one of the following mechanisms:

- In-running nips between two counter-rotating parts
- In-running nips between a rotating surface and a tangentially moving surface.

(**Figures 8 and 13**)

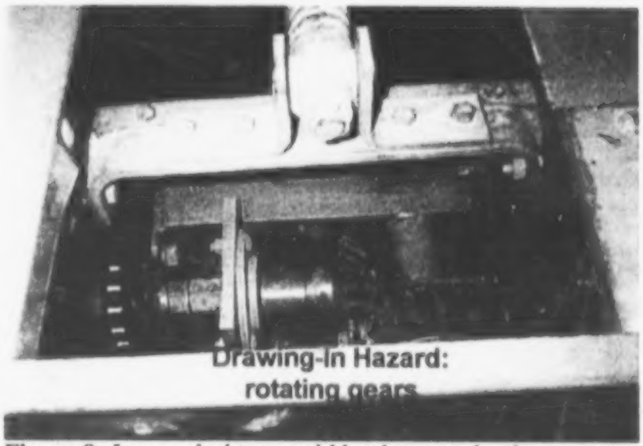
Drawing-In Hazard:
rotating gears

Figure 8. *Loose clothing could be drawn in by these gears on a square baler.*

Pinch Points

Where two parts move together and at least one of them moves in a circle; also called mesh points, run-on points, and entry points (e.g. belt drives, chain drives, gear drives, and feed rolls). (**Figures 6, 9, and 16**)

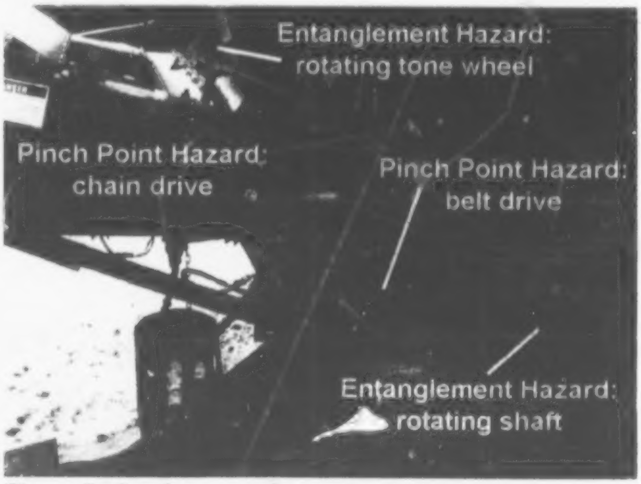
Entanglement Hazard:
rotating tone wheel
Pinch Point Hazard:
chain drive
Pinch Point Hazard:
belt drive
Entanglement Hazard:
rotating shaft

Figure 9. *Combines can be particularily dangerous because of multiple danger zones.*

Thrown Objects

Any object that can become airborne because of moving parts (e.g. rocks, stones, sticks, and pieces of chopped or cut crops). (**Figure 10**)

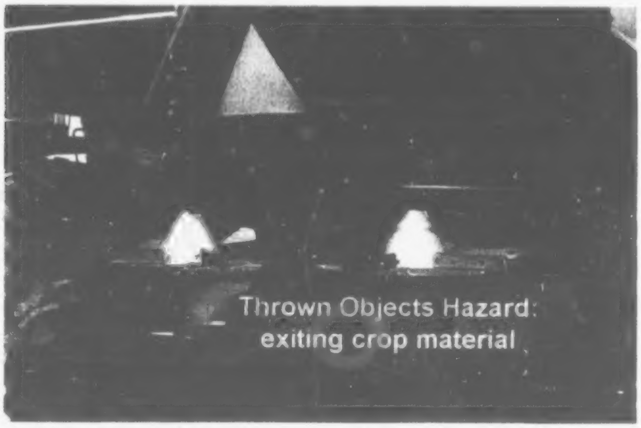
Thrown Objects Hazard:
exiting crop material

Figure 10. *Combine choppers and spreaders can be hazardous because of crop material or objects that become airborne.*

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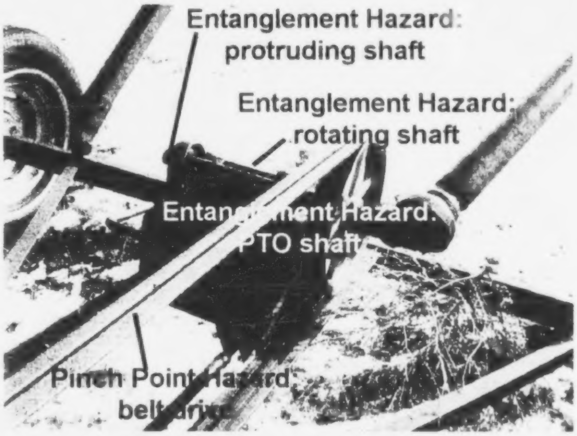
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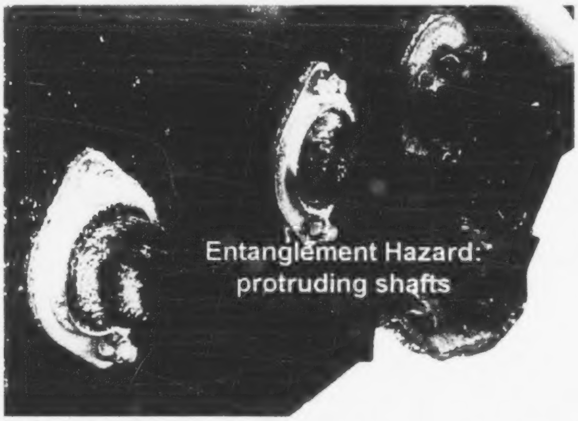
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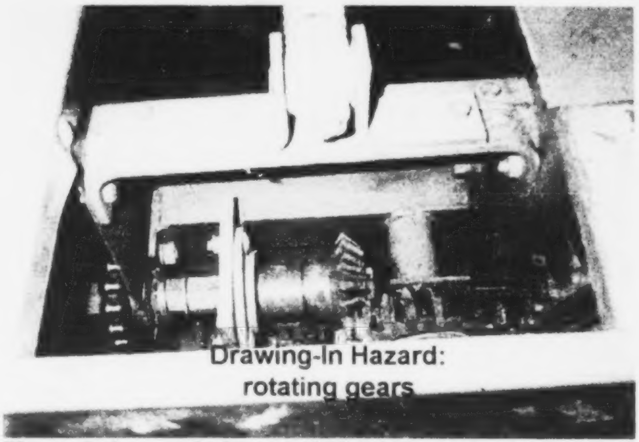
Drawing-In Hazard:
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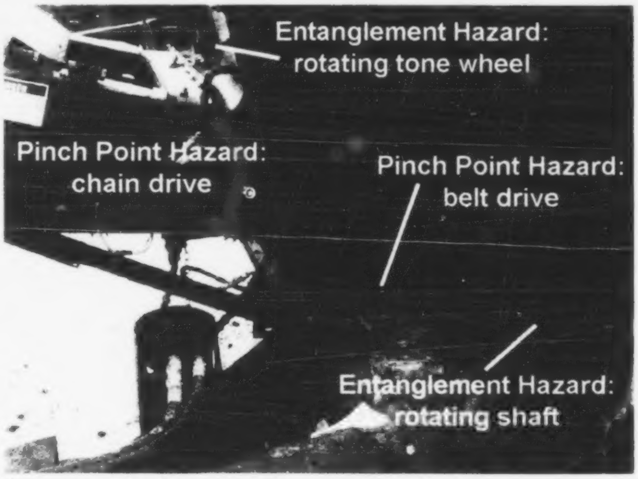
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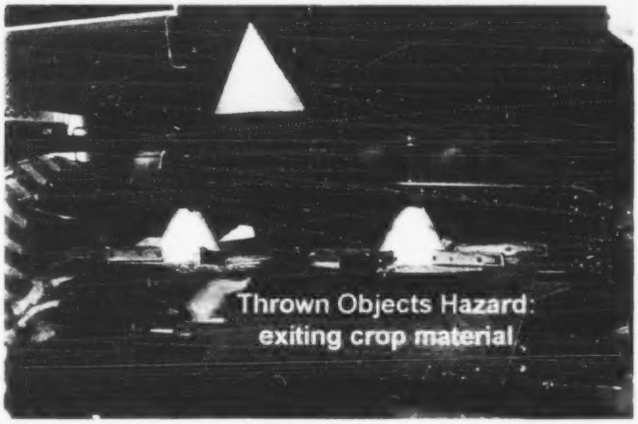

Thrown Objects Hazard:
exiting crop material

Figure 10. *Combine choppers and spreaders can be hazardous because of crop material or objects that become airborne.*

PAMI Recommendation:
To reduce the likelihood of stones and other objects being thrown at people, install a rubber or chain skirt around the openings and perimeter of rotary mowers and flails.

Cutting

Cutting occurs as a result of bodily contact with such items as cutting tools, blades, knives, or sharp parts. (**Figure 11**)

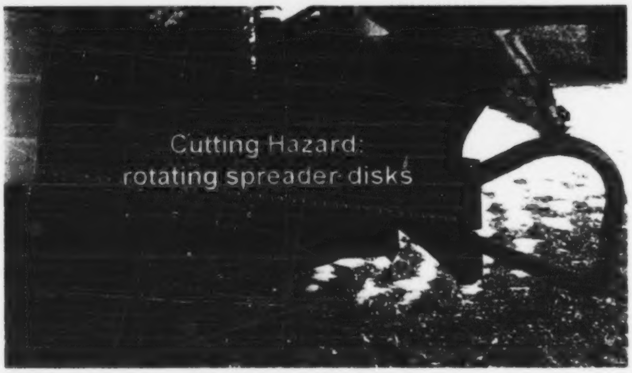

Cutting Hazard:
rotating spreader disks

Figure 11. *The spinning spreader discs of combines should have a distance guard similar to the one in this picture.*

Shear

Parts of the body may be sheared between two machine parts or between a machine part and a work piece (e.g. rotary shredders and cutters, augers in tubes, chain and paddle conveyors). (**Figure 12**)

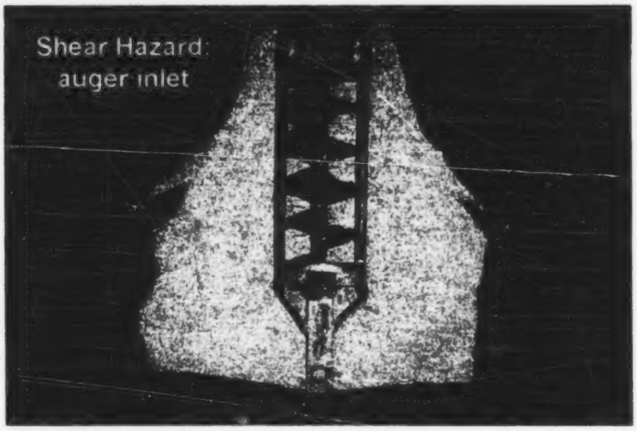

Shear Hazard:
auger inlet

Figure 12. *Auger inlets are often left unguarded.*

Impact

Impact occurs as the result of bodily contact with objects acting against the body, but not penetrating it. (**Figure 13**)

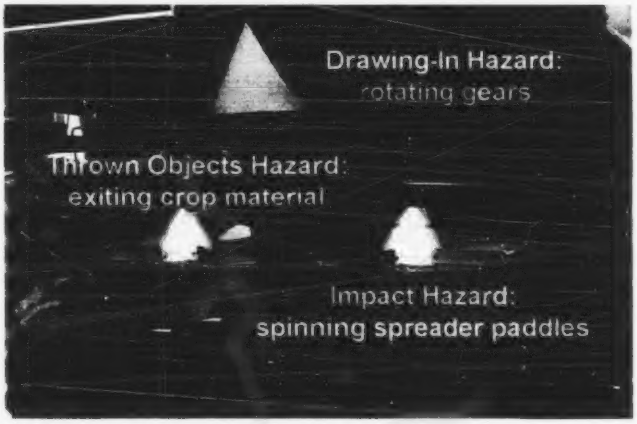

Drawing-In Hazard:
rotating gears
Thrown Objects Hazard:
exiting crop material
Impact Hazard:
spinning spreader paddles

Figure 13. *The rear discharge area of combines have multiple danger zones.*

Crushing

Crushing occurs as the result of bodily contact between one part of machinery moving against another part. (**Figure 14**)

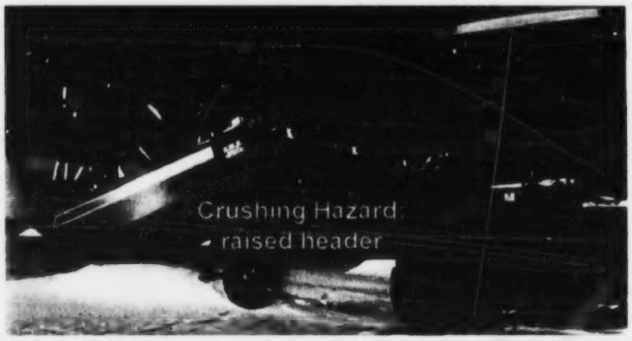
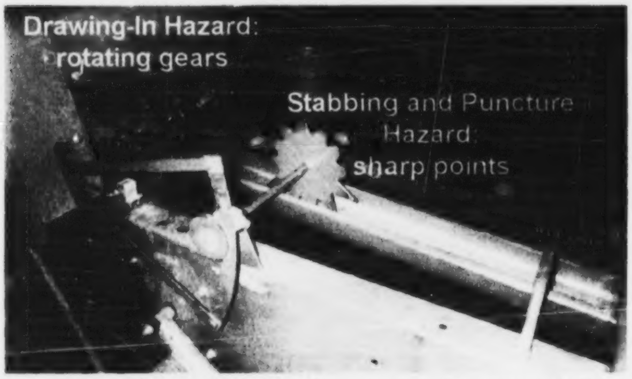

Crushing Hazard:
raised header

Figure 14. *The crushing hazard under raised headers can be eliminated by using hydraulic cylinder stops.*

Stabbing and Puncture

The body may be penetrated by flying objects or by rapidly moving parts. (**Figure 15**)


Drawing-In Hazard:
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Stabbing and Puncture Hazard:
sharp points

Figure 15. *Sharp edges like the ones on this square baler are a stabbing or puncture hazard.*

Friction and Abrasion

Friction and Abrasion occur as the result of bodily contact with relatively smooth parts operating at high speeds (e.g. The outside face of a pulley) or abrasive hazards (e.g. abrasive wheels or belt sanders). (**Figure 16**)

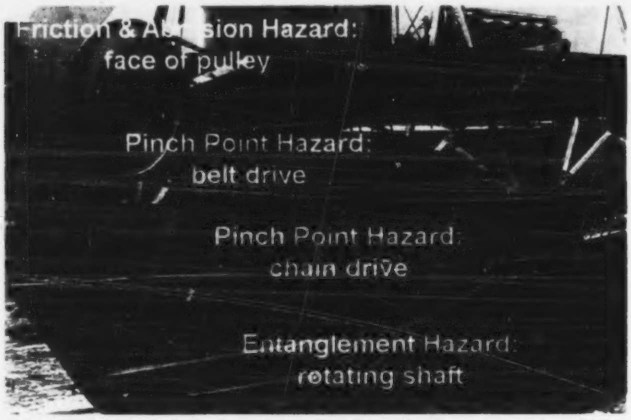
Friction & Abrasion Hazard:
face of pulley
Pinch Point Hazard:
belt drive
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Figure 16. *The header drives of windrowers are often left unguarded.*

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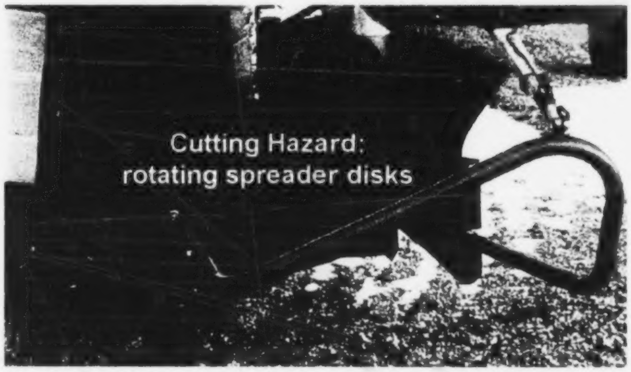
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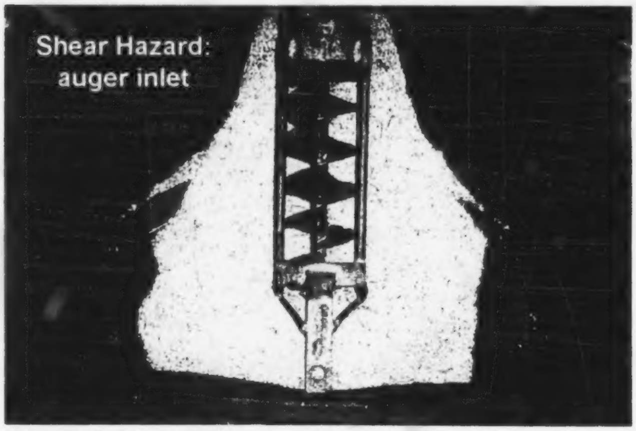
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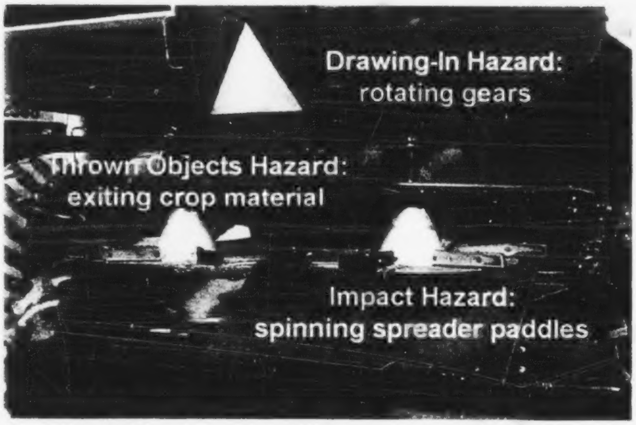
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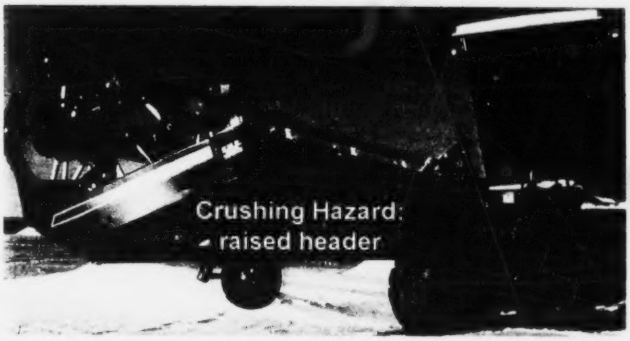
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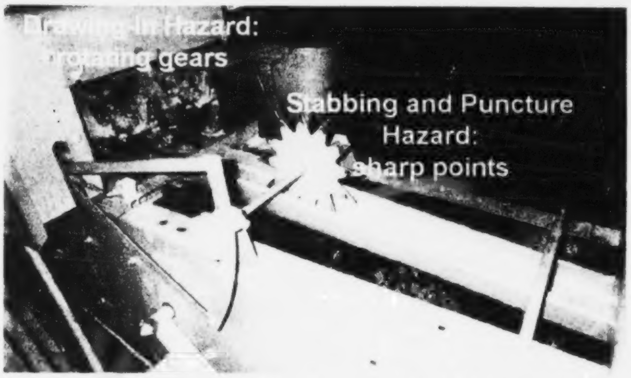
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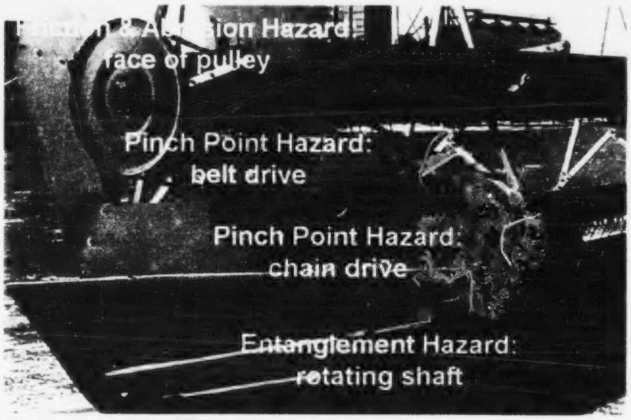
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chain drive
Entanglement Hazard:
rotating shaft

Figure 16. *The header drives of windrowers are often left unguarded.*

Compressed Air or High-pressure Fluid Injection

Compressed air or high-pressure fluid injection occurs as the result of skin exposure to high-pressure streams such as compressed air jets, high-pressure water, or steam, or hydraulic systems. (**Figure 17**)

High-pressure Injection Hazard:
hydraulic components near operator

Figure 17. *Pin hole hydraulic leaks are a hazard to the skin and eyes.*

PAMI Recommendation:
Whenever practical, hydraulic components and hoses should be positioned away from the operator zone or areas where people may be at risk. Consider re-routing hydraulic hoses away from the operator station. As an alternative, place the components and hoses behind guards. Use cardboard to source pinhole leaks in hydraulic systems, not your hand.

Heat

Any surface that reaches a temperature of 130°C (266°F) is considered a hot surface and should be guarded. (**Figure 18**)

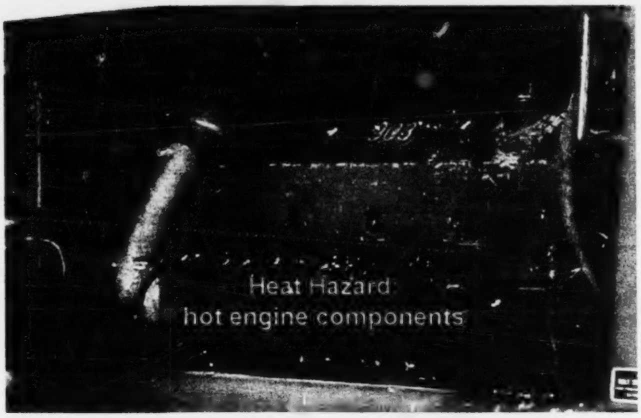

Figure 18. *Hot engine components that often need proper ventillation can be made safe with distance guards.*

[illegible]
Skin burns will occur at surface temperatures below 130°C (266°F). Guard hot components where inadvertent contact is possible.

Electrical

Bare wires and unguarded battery posts pose potential spark hazards. Locate batteries away from operators or bystanders. (**Figure 19**)

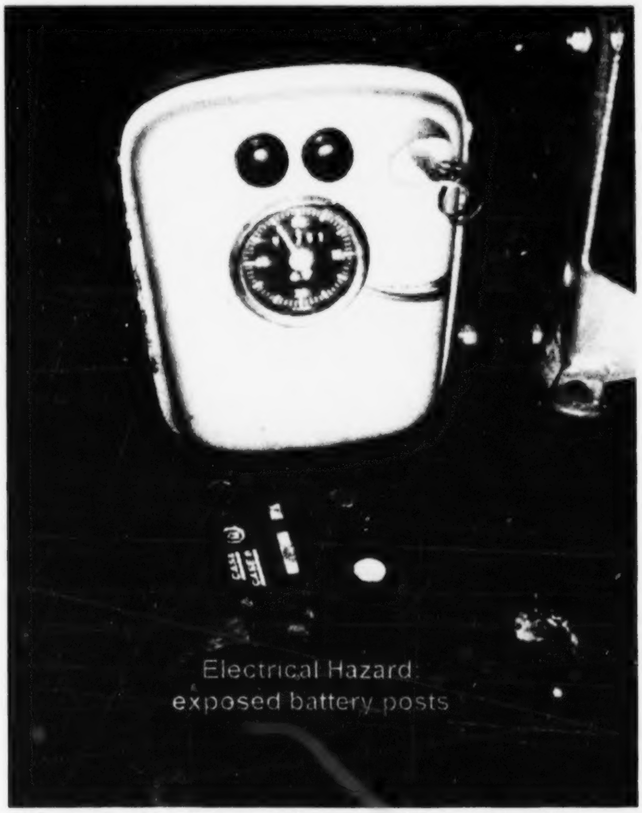

Figure 19. *This electrical hazard could easily be eliminated by battery post covers or a battery box.*

2.4 Guard Design, Fabrication, and Attachment

2.4.1 Guard Principles

The principles below apply to guard design and construction for new farm machinery. These principles can also be used to provide guidance in the design and fabrication of guards for used machinery.

- Guards should not interfere with the normal operation of the machine.
- Guards should normally be permanently attached, which includes the use of threaded fasteners, split pins, hinges, or other methods that can be dismantled with common hand tools.
- Guards and access doors which must be opened for routine or daily service, inspection or cleaning should:
    - Be easy to open and close.
    - Remain attached when open; for example, by means of a hinge, slide, linkage, tether or other suitable methods.
    - Include a convenient and effective way to keep them closed.
- Guards should remain functional under the forces that could be applied by a 123 kg (270 lb) person leaning, stepping, or falling against them in normal operation or servicing of equipment.

Compressed Air or High-pressure Fluid Injection

Compressed air or high-pressure fluid injection occurs as the result of skin exposure to high-pressure streams such as compressed air jets, high-pressure water, or steam, or hydraulic systems. (**Figure 17**)

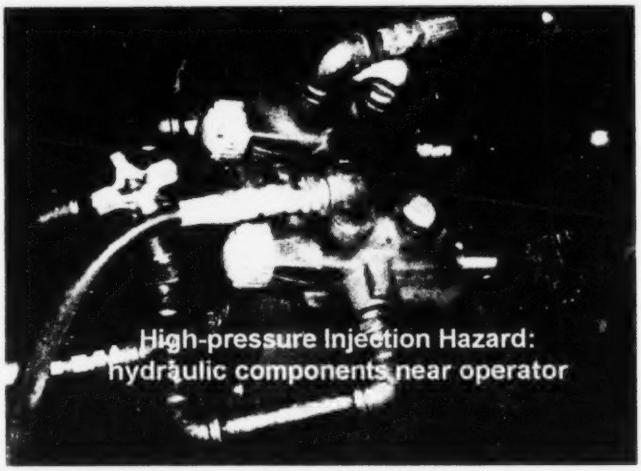
High-pressure Injection Hazard:
hydraulic components near operator

Figure 17. *Pin hole hydraulic leaks are a hazard to the skin and eyes.*

PAMI Recommendation:
Whenever practical, hydraulic components and hoses should be positioned away from the operator zone or areas where people may be at risk. Consider re-routing hydraulic hoses away from the operator station. As an alternative, place the components and hoses behind guards. Use cardboard to source pinhole leaks in hydraulic systems, not your hand.

Heat

Any surface that reaches a temperature of 130°C (266°F) is considered a hot surface and should be guarded. (**Figure 18**)

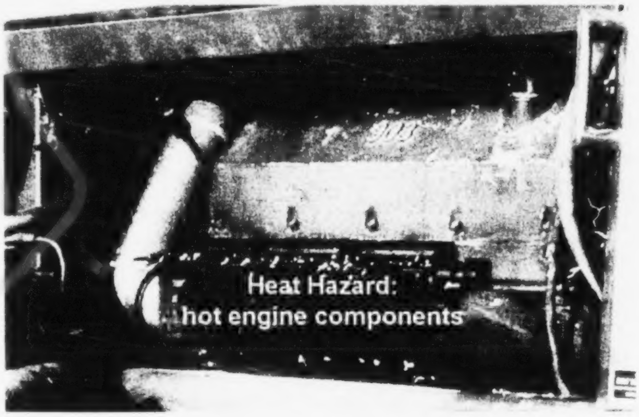

Figure 18. *Hot engine components that often need proper ventillation can be made safe with distance guards.*

PAMI Recommendation:
Skin burns will occur at surface temperatures below 130°C (266°F). Guard hot components when inadvertent contact is possible.

Electrical

Bare wires and unguarded battery posts pose potential spark hazards. Locate batteries away from operators or bystanders. (**Figure 19**)

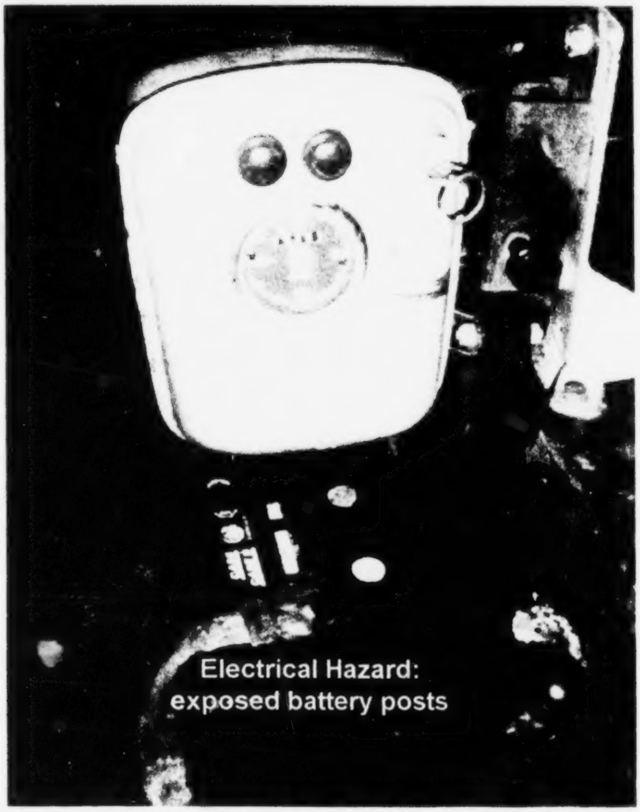

Figure 19. *This electrical hazard could easily be eliminated by battery post covers or a battery box.*

2.4 Guard Design, Fabrication, and Attachment

2.4.1 Guard Principles

The principles below apply to guard design and construction for new farm machinery. These principles can also be used to provide guidance in the design and fabrication of guards for used machinery.

- Guards should not interfere with the normal operation of the machine.
- Guards should normally be permanently attached, which includes the use of threaded fasteners, split pins, hinges, or other methods that can be dismantled with common hand tools.
- Guards and access doors which must be opened for routine or daily service, inspection or cleaning should:
  - Be easy to open and close.
  - Remain attached when open; for example, by means of a hinge, slide, linkage, tether or other suitable methods.
  - Include a convenient and effective way to keep them closed.
- Guards should remain functional under the forces that could be applied by a 123 kg (270 lb) person leaning, stepping, or falling against them in normal operation or servicing of equipment.

- Guards should be designed and constructed with the object of preventing any part of the body from reaching a dangerous point or area.
- The design of guarding should ensure that the guards do not present a hazard such as trapping, shear points, rough or sharp edges, or other hazards likely to cause injury.
- Guard mountings should be compatible with the strength and duty of the guard.
- Guarding, where required, should minimize inadvertent contact with machinery hazards during normal mounting, starting, operating, dismounting, and servicing of the equipment. Operating instructions should be provided stating that guards must be kept in place, and/or that the machine should not be operated with guards removed.
- Guards should be weather resistant,and retain required strength under expected climatic and operational conditions for their intended use.
- Guards should not cause undue obstruction to the view of a process.
- Guards should be installed so that they do not cause interference with the activities of workers during operation, maintenance, etc. A proper installation should reduce any incentive to operate the machine without guarding.
- Guards should be permanently affixed to the machine, or, when this is not possible, to the same surface to which the machine is fixed. The removal of a fixed guard should require the use of tools. Fasteners should stay attached to the guard.
- Guards should protect an operator and others in the vicinity from materials, work pieces, chips, liquids, dust, fumes, gases, etc, that may be ejected, dropped, or emitted from a machine and that may present a hazard.
- Guards should allow for safe lubrication, inspection, and maintenance of the hazard area.

STATISTIC: *In Canada there are an average of 228 hospitalized injuries per year where entanglement in agricultural machinery was the cause of injury. Entanglement is the leading mechanism of hospitalized injuries relating to agricultural machinery, accounting for 32 percent of all cases.*[5]

2.4.2 Guard Type and Classification

There are 2 main guard types associated with agricultural equipment:

- A **fixed guard** is a guard that is kept in place (i.e. closed) either permanently (by welding, etc.) or by means of fasteners (screws, nuts, etc.) making removal/opening impossible without the use of common hand tools.
- A **moveable guard** is a guard generally connected by mechanical means (e.g. hinges or slides) to the machine frame or an adjacent fixed element and which can be opened without the use of tools.

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5. CAISP. 2003.

Each guard type may be classified as one of the following:

- A **local enclosing guard** alone or with other parts of the machine, provides protection from individual danger zones. (**Figure 20**)

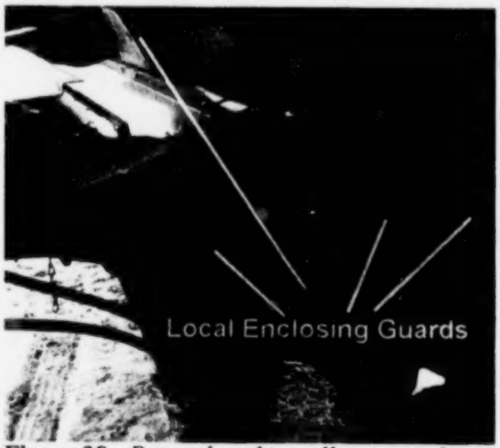
Local Enclosing Guards

Figure 20. *Remember this pull-type combine from Figure 9?*

- A **local distance guard** is used when an enclosing guard is not practical to guard a low number of danger zones. It provides protection to individual danger zones by keeping people at a safe distance from the danger zone. (**Figure 21**)

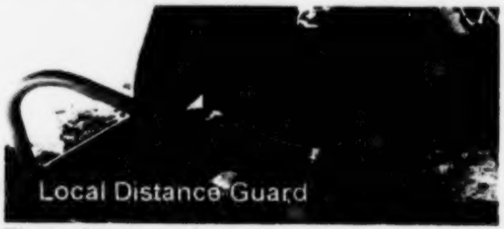
Local Distance Guard

Figure 21. *An enclosing guard would interfere with the function of this combine spreader disc.*

- A **fully enclosed guard** is used to guard multiple danger zones. It alone, or with other parts of the machine, provides protection on all sides. (**Figure 22**)

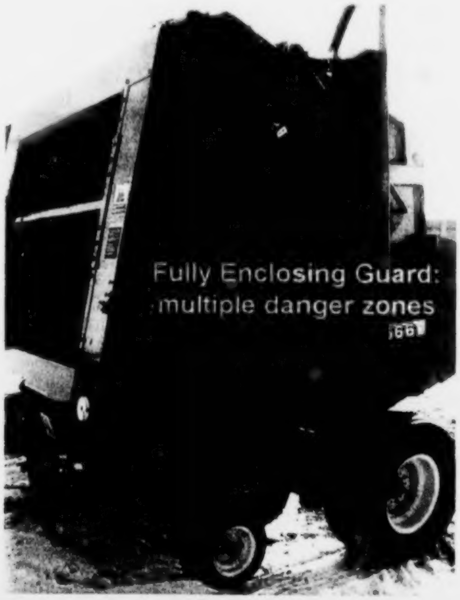
Fully Enclosing Guard:
multiple danger zones

Figure 22. *One fully enclosing guard can often eliminate multiple danger zones like on this round baler.*

Each guard type may be classified as one of the following:

- A **local enclosing guard** alone or with other parts of the machine, provides protection from individual danger zones. (**Figure 20**)

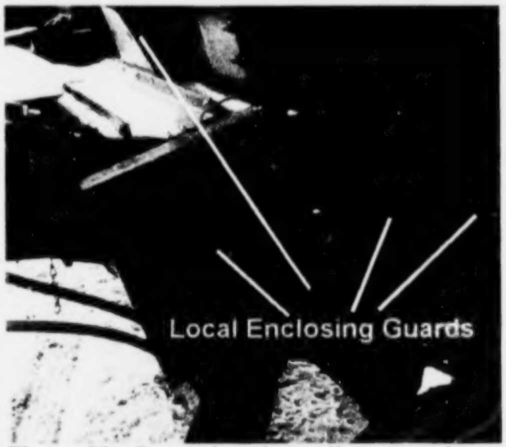
Local Enclosing Guards

Figure 20. *Remember this pull-type combine from Figure 9?*

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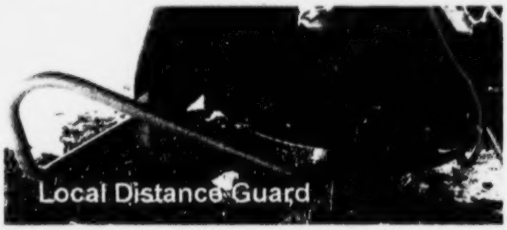
Local Distance Guard

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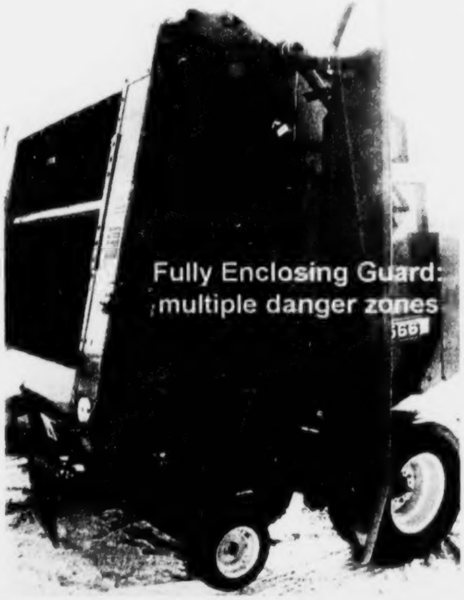
Fully Enclosing Guard:
multiple danger zones

Figure 22. *One fully enclosing guard can often eliminate multiple danger zones like on this round baler.*

- A **fully surrounding distance guard** is a guard such as a rail, fence, or frame which is used when an enclosing guard is impractical and there are multiple danger zones. (**Figure 23**)

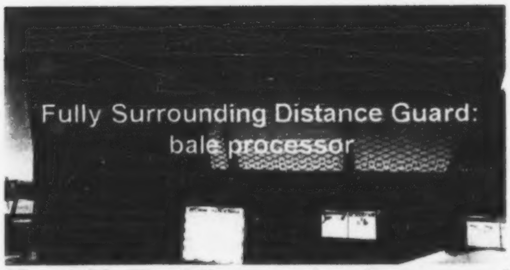

Figure 23. *This fully surrounding distance guard is designed to keep people at a safe distance from the danger zone. Notice the expanded mesh still provides viewing of the process.*

2.4.3 Guard Selection Criteria

Before fabrication of a guard, it is important to consider the following factors:

Frequency of Access to the Hazard

Consider the number of occasions on which access is required or foreseeable within the guarded area for a given period of time.

To minimize access to hazards where practical, guards and machinery shall be designed to enable routine adjustments, lubrication, and maintenance to be carried out without opening or removing the guards.

Where access is required within a guarded area, it shall be as free and unobstructed as practical. The following are examples of reasons for access:

- Loading and unloading material
- Tool changing and setting
- Measurement, gauging, and sampling
- Process observation
- Maintenance and repair
- Lubrication
- Removal of waste material
- Obstruction removal
- Machine cleaning

Where access is not required during use, fixed guards should be used because of their simplicity and reliability.

Viewing of Process or Components Being Guarded

Where viewing of machine operation is required through the guard, materials should be selected with suitable properties, e.g., if perforated material or wire mesh is used, this should be of adequate open area and suitable color to permit viewing. Viewing will be enhanced if the perforated material is darker than the area observed.

[illegible]

Where possible, install extended [illegible] lines so lubrication can be done without the removal of guards. Consider routing all lubrication lines to one lube bank in a safe location. Lubrication lines and banks are common on new agricultural machinery. Your local dealer can assist in the selection of these components.

Size and Weight

A guard should not be too large or heavy for one person to remove or open.

PAMI Recommendation:
If a guard is frequently removed or opened (once per day) it should take no longer than 30 seconds to be removed or attached by one person. This will increase the likelihood of the guard being re-installed.

Durability

The ASAE standard states that a guard must withstand a force of a123 kg (270 lb) individual leaning or falling against the guard. Be sure guards are durable enough to withstand any forces that they may see in their lifetime.

Reliability of Moving Guard Parts

If a guard is movable as a result of hinges, latches, slides, or handles, be sure that these components are durable enough to withstand any abuse over the entire life of the machine.

STATISTIC: *Tractors, augers, combines, and PTO shafts account for 50 percent of all agricultural machinery related hospitalized injuries in Canada.*[6]

Impact Resistance

The guard should withstand any foreseeable impact forces. Some examples of impact forces are: Persons falling against them, broken part ejection, or airborne material.

Crushing or Trapping Points Created

A guard should be safe to remove or open. Attention should be given to the attachment or latching points to ensure they will not pinch fingers or trap clothing.

Sharp Edges

Guards should be free of sharp edges, corners, or other hazardous projections which could catch clothing or cause cuts.

Secure Fixing

Guards should be securely fixed to the machine and able to withstand any vibration or forces during normal machine operation.

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6. CAISP. 2003.

- A **fully surrounding distance guard** is a guard such as a rail, fence, or frame which is used when an enclosing guard is impractical and there are multiple danger zones. (**Figure 23**)

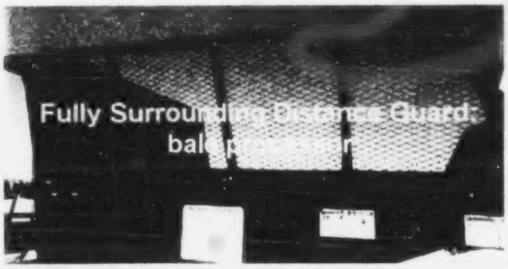

Figure 23. *This fully surrounding distance guard is designed to keep people at a safe distance from the danger zone. Notice the expanded mesh still provides viewing of the process.*

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Secure Fixing

Guards should be securely fixed to the machine and able to withstand any vibration or forces during normal machine operation.

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6. CAISP, 2003.

Warning Signs

Where access within the guarded area can expose persons to residual risks, appropriate warning signs shall be placed near the latching or attachment points. Warning signs warn of the hazards being guarded and remind people not to operate the machinery without guarding in place. See **Appendix V** for standard warning decals and where to get them. (**Figures 24 and 25**)

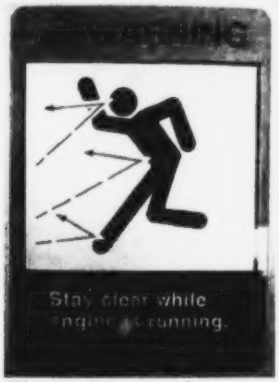
WARNING
Stay clear while engine is running.

Figure 24. *A safety decal warning of a thrown objects hazard.*

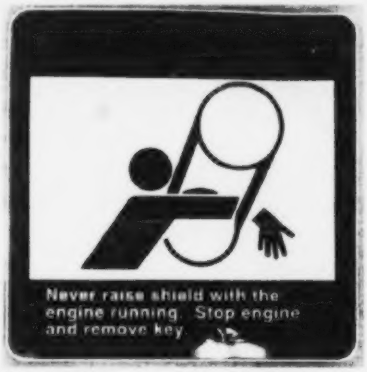
Never raise shield with the engine running. Stop engine and remove key.

Figure 25. *A safety decal warning of a pinch point hazard from a belt drive.*

Resistance to Corrosion

Be sure to paint the guard to ensure it does not rust. Galvanized metal is a good guard material, as it will not rust.

Colors

Hazards can be highlighted by the use of suitable colors. For example, if a guard is painted the same color as the machine and the hazardous parts painted a contrasting bright color, attention is drawn to the hazard when the guard is open or left off.

Guard Latching Types and Attachment Methods

Where practical, guard fastenings shall remain attached to the guard as this reduces the likelihood of being lost and not replaced. See **Appendix VI** for a guard attachment component guide. Listed below are common guard attachment methods for agricultural machinery:

- Bolted (fixed) (**Figure 26**)
- Hinged / Latched (**Figure 27**)
- Hinged / Pinned (**Figure 28**)
- Dowels / Pinned (**Figure 29**)
- Sliding / Pinned (**Figure 30**)
- Slot and Tab / Pinned (**Figure 31**)

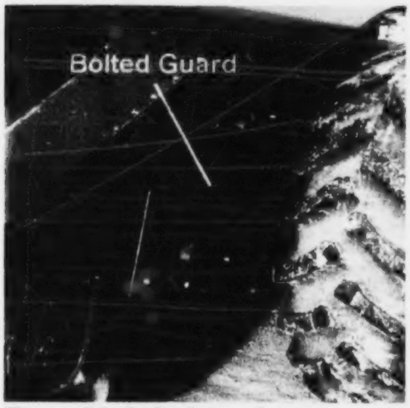

Figure 26. *Bolted Attachment*

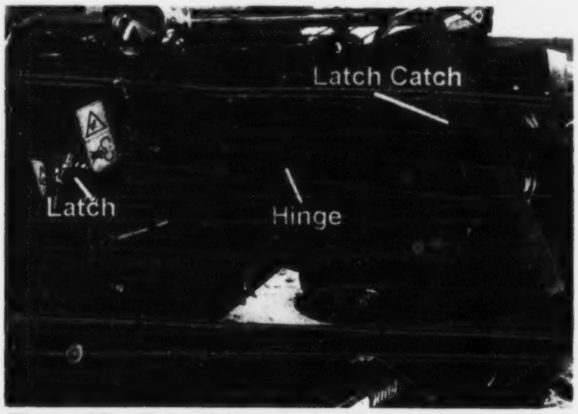

Figure 27. *Hinged / Latched Attachment*

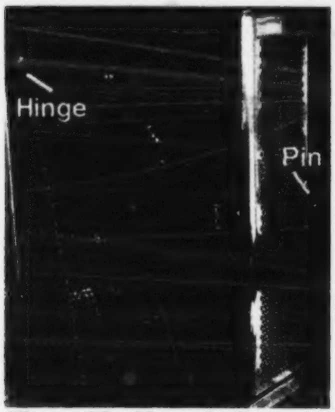

Figure 28. *Hinged / Pinned Attachment*

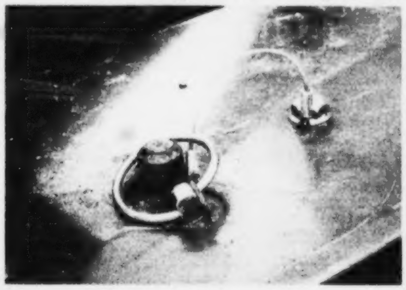

Figure 29. *Dowel / Pinned Attachment*

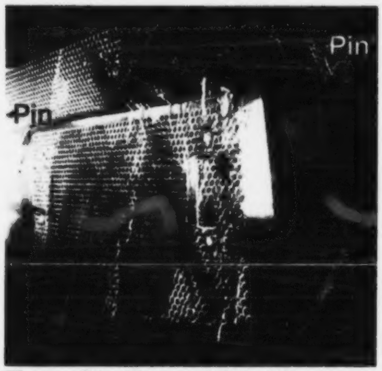

Figure 31. *Slot and Tab / Pinned Attachment*

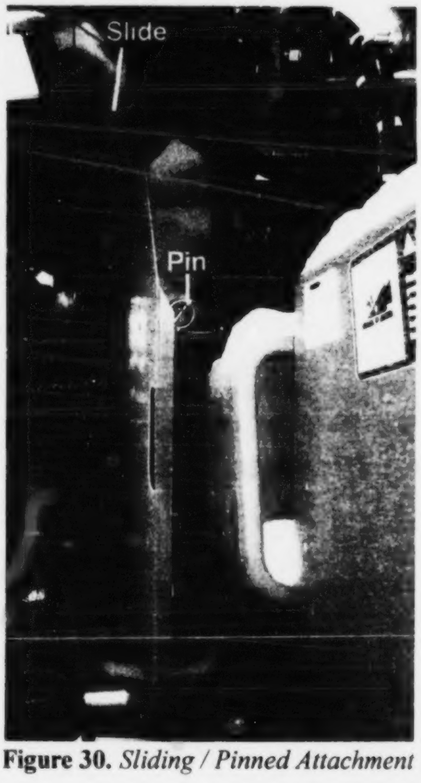

Figure 30. *Sliding / Pinned Attachment*

Warning Signs

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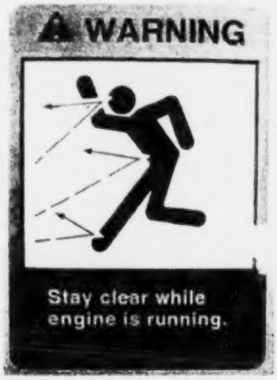
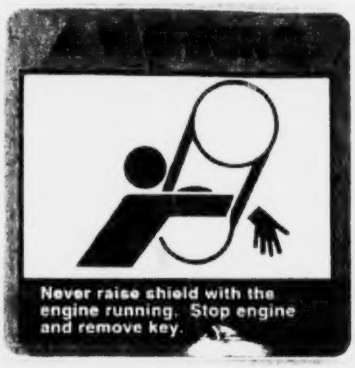

WARNING
Stay clear while engine is running.

Figure 24. *A safety decal warning of a thrown objects hazard.*


Never raise shield with the engine running. Stop engine and remove key.

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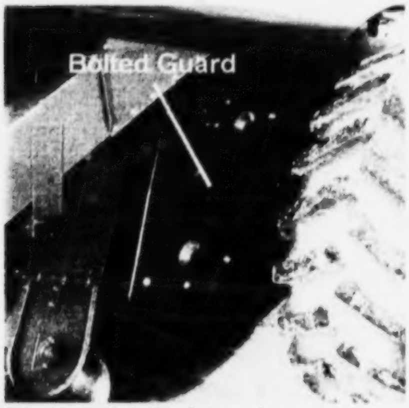


Figure 26. *Bolted Attachment*

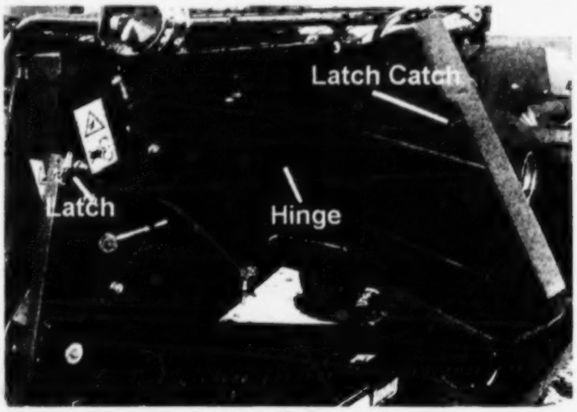


Figure 27. *Hinged / Latched Attachment*

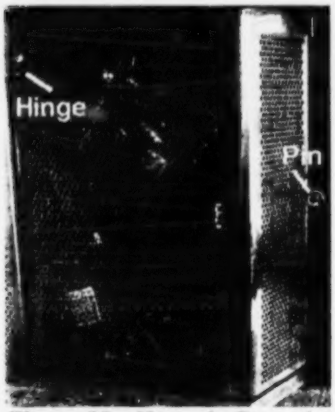
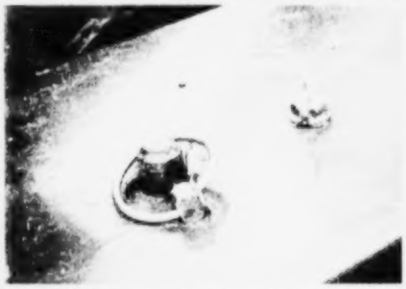


Figure 28. *Hinged / Pinned Attachment*



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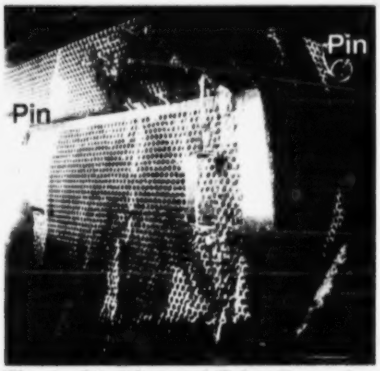

Figure 31. *Slot and Tab / Pinned Attachment*

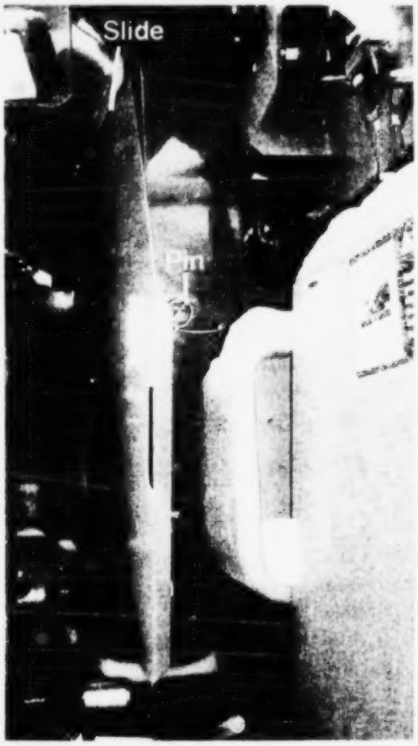

Figure 30. *Sliding / Pinned Attachment*

2.4.4 Guard Material Suggestions

If a shield or enclosure is to be fabricated where there is at least one side to be completely guarded, it is recommended to use sheet steel. This steel sheet can either be solid sheet metal, expanded mesh, or perforated sheet metal. Viewing of the hazard through the guard is easier if expanded or perforated sheet metal is used. The suggested material can be purchased from any steel supplier, which can be found under "steel" in the yellow pages of your phone book. Also, search for steel suppliers on the PIMA - Agricultural Manufacturers of Canada website (www.pima.ca) under the member search area.

All prices listed below were estimated at the time this guide was written (2003).

Solid sheet metal provides the best protection from a hazard. It does not allow ejection of any material or failed parts. (**Figure 32**) It will not provide viewing of the hazard through the guard so it may be more often removed or opened. When ordering solid sheet metal from a steel supplier these are the specifications needed:

- Material - Mild steel
- Sheet thickness - 16 gauge (0.06 in)
- Dimensions – Width X Length required (stock size is 4 ft X 8 ft)
- Estimated price – $1.10 to $1.20 / sq ft

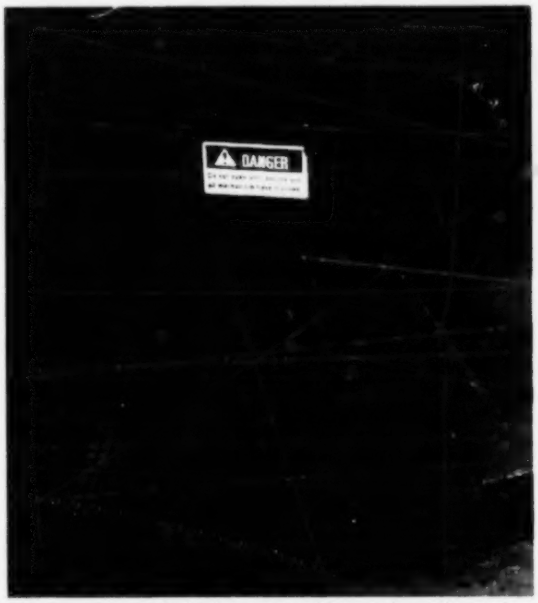

Figure 32. *Solid Sheet Metal Guard on the side of a combine.*

(Picture Courtesy of Bourgault Industries)

Expanded mesh allows viewing of the hazard, ventilation of the hazard, and drainage of fluids or material through the openings in the bottom of the guard. It also provides weight reduction for the guard. (**Figure 33**) When ordering perforated sheet metal from a steel supplier these are the specifications needed:

- Material – Mild steel
- Style – ½ in - 16 Standard diamond
- Dimensions – Width X Length required (stock size is 4 ft X 8 ft)
- Estimated price – $0.75 to $0.90 / sq ft

Figure 33. *An Expanded Mesh Guard like the one on this grain cart allows viewing of the hazard without removal of the guard.*

Perforated sheet metal possesses the same guarding characteristics as expanded metal, but is more expensive. This is the most common material used for guarding on new equipment because it is more esthetically appealing than expanded metal. When ordering perforated sheet metal from a steel supplier these are the specifications needed:

- Material – Mild steel
- Sheet thickness – 16 gauge
- Dimensions – Width X Length required (stock size is 4 ft X 8 ft)
- Perforation size – ¼ in diameter
- Perforation pattern – 3/8 in staggered centers
- Estimated price – $4.20 to $4.90 / sq ft

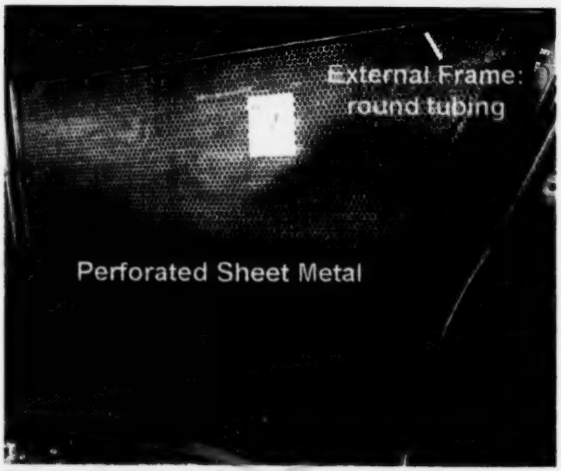

Figure 34. *This perforated sheet metal guard provides protection from all sides and allows viewing of the hazard without opening the guard.*

Round tubing works well in constructing the external framing for sheet metal guards. (**Figure 34**) When ordering round tubing from a steel supplier these are the specifications needed:

- Material – ERW Mild steel
- Wall thickness – 16 gauge
- Dimensions – ¾ in OD X Length required (stock length is 20 ft)
- Estimated price - $0.45 to $1.00 / ft

Not all guards will be enclosures. Where distance barriers are required, material such as Schedule 40 pipe or square tubing is recommended. When ordering pipe from a steel supplier, these are the specifications needed:

Schedule 40 Pipe:

- Material – Mild steel
- Dimensions – 1 in diameter X Length required (stock length is 21 ft)
- Estimated price – $0.85 to $1.00 / ft

Square Tubing:

- Material – ERW Mild steel
- Wall thickness – 16 gauge
- Dimensions – 1 in square X Length required (Stock length is 20 ft)
- Estimated price - $0.65 to $1.15 / ft

STATISTIC: *For every 21 hospitalized injuries related to entaglements in agricultural machinery there is 1 fatality in Canada.*[7]

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[7] CAISP. 2003.

Perforated sheet metal possesses the same guarding characteristics as expanded metal, but is more expensive. This is the most common material used for guarding on new equipment because it is more esthetically appealing than expanded metal. When ordering perforated sheet metal from a steel supplier these are the specifications needed:

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- Sheet thickness – 16 gauge
- Dimensions – Width X Length required (stock size is 4 ft X 8 ft)
- Perforation size – ¼ in diameter
- Perforation pattern – 3/8 in staggered centers
- Estimated price – $4.20 to $4.90 / sq ft

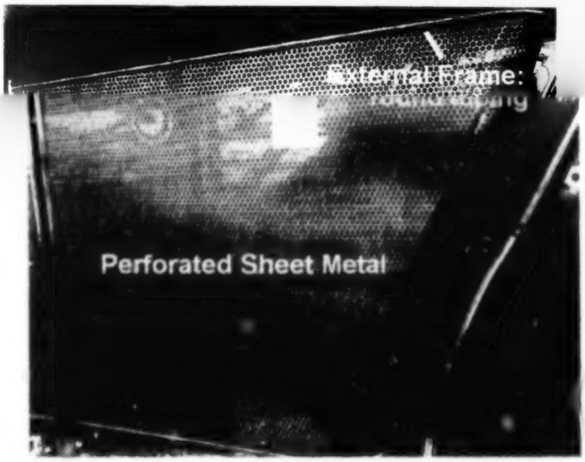

Figure 34. *This perforated sheet metal guard provides protection from all sides and allows viewing of the hazard without opening the guard.*

Round tubing works well in constructing the external framing for sheet metal guards. (**Figure 34**) When ordering round tubing from a steel supplier these are the specifications needed:

- Material – ERW Mild steel
- Wall thickness – 16 gauge
- Dimensions – ¾ in OD X Length required (stock length is 20 ft)
- Estimated price - $0.45 to $1.00 / ft

Not all guards will be enclosures. Where distance barriers are required, material such as Schedule 40 pipe or square tubing is recommended. When ordering pipe from a steel supplier, these are the specifications needed:

Schedule 40 Pipe:

- Material – Mild steel
- Dimensions – 1 in diameter X Length required (stock length is 21 ft)
- Estimated price – $0.85 to $1.00 / ft

Square Tubing:

- Material – ERW Mild steel
- Wall thickness – 16 gauge
- Dimensions – 1 in square X Length required (Stock length is 20 ft)
- Estimated price - $0.65 to $1.15 / ft

⚠ **STATISTIC:** *For every 21 hospitalized injuries related to entaglements in agricultural machinery there is 1 fatality in Canada.*[7]

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[7] CAISP. 2003.

2.4.5 Safety Distance Guarding

Safety distance guarding is minimizing the possibility of inadvertent contact with the hazard by the combination of the guard configuration (including openings) and the distance between the guard and the hazard. (**Figures 35, 36, and 37**)

- Consider safety distances when using expanded or perforated metal for the purpose of viewing a hazard through a guard. The distance that the surfaces of the guard should be away from the hazard depends on the size of the [illegible]
- It can be assumed that no reach is possible through an opening less than 10mm (3/8 in) square, as fingers do not fit in these size of openings. An opening 38 mm (1.5 in) square is the maximum safe opening permissible at a distance of 100 mm (4 in) from the hazard.
- The distance one can reach upwards from the ground or from any working platform is considered to be 2.5 m (8 ft - 2 in).
- Safety distance guarding should also be practiced when using barriers as guards. Perimeter fences serving as guards should be at least 1.8 m (5 ft – 11 in) high. The height of the barrier and location of the hazard determines how far away the barrier must be from the hazard. Ensure that by reaching up, over, around, or along, the barrier the hazard can't be accessed.

See **Appendix IV** for detailed information from ASAE on safety distance guarding.

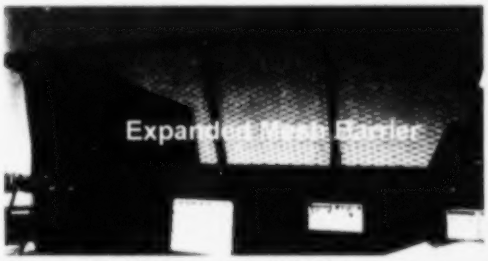

Figure 35. *This expanded mesh barrier keeps people at a safe distance away from the rotating flails of a bale processor.*

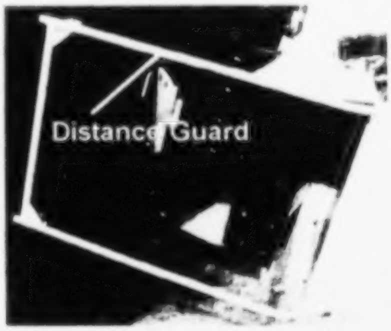

Figure 36. *The distance guard on this feed processor keeps workers at a safe distance from the rotating knives when the cover is open.*

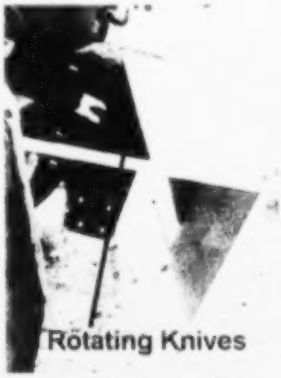

Figure 37. *The worker cannot reach into the 'danger zone.'*

PAMI Recommendation:
The effectiveness of a guard with openings or a distance barrier should be judged by a reach test carried out with the machinery at rest in a safe condition. Keep in mind a person can reach upwards, over, around, along, and into to access a danger zone.

2.5 Is the Machine Safe?

After guarding the machine, it is important to step back and ensure that the machine is safe. Ensure there is no interference between the guards and the hazards. Inspect the guards after the machine's first use to be sure there is no rubbing, excess vibration, or material build-up around the guards.

2.4.5 Safety Distance Guarding

Safety distance guarding is minimizing the possibility of inadvertent contact with the hazard by the combination of the guard configuration (including openings) and the distance between the guard and the hazard. (**Figures 35, 36, and 37**)

- Consider safety distances when using expanded or perforated metal for the purpose of viewing a hazard through a guard. The distance that the surfaces of the guard should be away from the hazard depends on the size of the openings in the guard.
- It can be assumed that no reach is possible through an opening less than 10mm (3/8 in) square, as fingers do not fit in these size of openings. An opening 38 mm (1.5 in) square is the maximum safe opening permissible at a distance of 100 mm (4 in) from the hazard.
- The distance one can reach upwards from the ground or from any working platform is considered to be 2.5 m (8 ft - 2 in).
- Safety distance guarding should also be practiced when using barriers as guards. Perimeter fences serving as guards should be at least 1.8 m (5 ft – 11 in) high. The height of the barrier and location of the hazard determines how far away the barrier must be from the hazard. Ensure that by reaching up, over, around, or along, the barrier the hazard can't be accessed.

See **Appendix IV** for detailed information from ASAE on safety distance guarding.

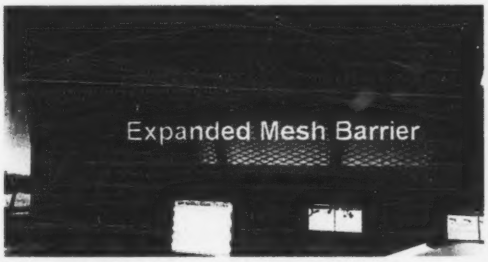

Figure 35. *This expanded mesh barrier keeps people at a safe distance away from the rotating flails of a bale processor.*

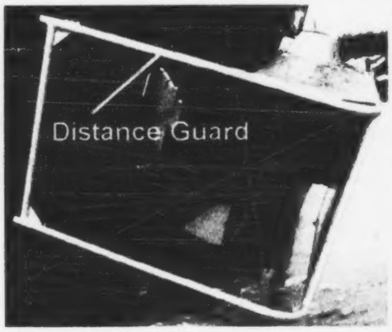

Figure 36. *The distance guard on this feed processor keeps workers at a safe distance from the rotating knives when the cover is open.*

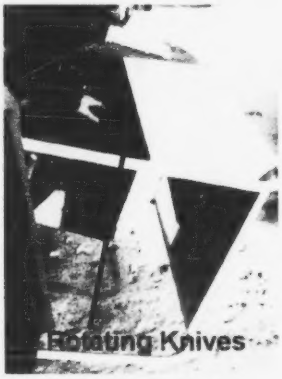

Figure 37. *The worker cannot reach into the danger zone.*

PAMI Recommendation:
The effectiveness of a guard with openings or a distance barrier should be judged by a reach test carried out with the machinery at rest in a safe condition. Keep in mind a person can reach upwards, over, around, along, and into to access a danger zone.

2.5 Is the Machine Safe?

After guarding the machine, it is important to step back and ensure that the machine is safe. Ensure there is no interference between the guards and the hazards. Inspect the guards after the machine's first use to be sure there is no rubbing, excess vibration, or material build-up around the guards.

3. Farm Machinery Guarding Example

3.1 Introduction

To show an actual example of the process, a portable grain auger was chosen because it is the third leading cause of machinery injuries on Canadian farms. Augers are associated with multiple hazards, not just the auger inlet. The precautions taken in this example, deal not only with guarding of hazards, but promote overall auger safety.

⚠ **STATISTIC:** *There are an average of 60 injuries per year in Canada where an auger was the cause of injury.*[8]

The Farm Machinery Guarding Procedure form in **Appendix VII** was used to guide the fabricator through the guarding procedure for the auger. Throughout the guarding of the auger, the time required, material used, and approximate cost were recorded.

3.2 Risk Assessment

What is the Function of the Machine?

The function of the auger is to convey grain from the auger inlet to the outlet at a higher position. Other things to keep in mind:

- A hand-powered winch can adjust the angle of incline of the auger.
- The auger is powered by an electric motor.
- From the electric motor, the auger is belt driven to a 90-degree gearbox, the power is then transmitted through a long drive shaft to the top of the auger, and lastly transmitted through a chain drive to the rotating auger screw.

What Hazards Exist?

How many hazards do you think are associated with an auger? We identified 8 hazards in 4 different areas on this particular auger! The auger inlet guard was already in place on this auger, are your auger inlets guarded? The chain drive at the top of the auger and the majority of the long drive shaft were also guarded.

---

[8] CAISP. 2003.

- **Driver pulley (Figure 38)**:
  1. **Pinch Point hazard** between the pulley and the belt
  2. **Entanglement hazard** from the protruding shaft
  3. **Friction hazard** with the exposed outside face of the pulley

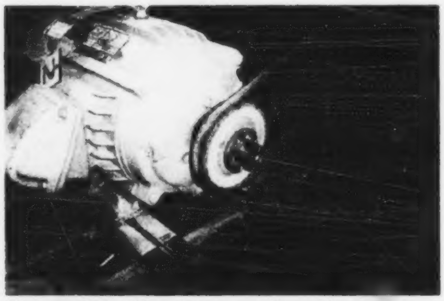

Figure 38. *The driver pulley of an auger.*

- **Driven pulley (Figure 39)**:
  4. **Pinch Point hazard** between the pulley and the belt.
  5. **Entanglement hazard** from the protruding shaft.
  6. **Friction hazard** with the exposed outside face of the pulley.

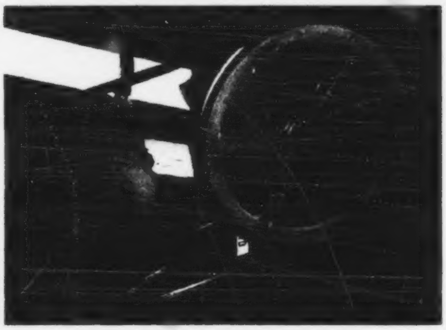

Figure 39. *The driven pulley of an auger.*

- **Drive shaft (Figure 40)**:
  7. **Entanglement hazard** from the drive shaft and exposed bolt where the existing shield is broken.

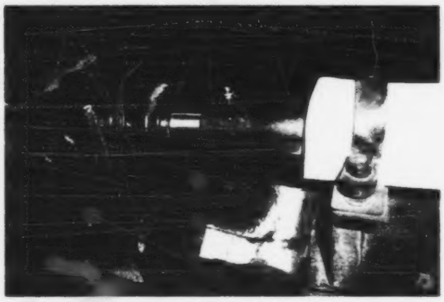

Figure 40. *The exposed drive shaft.*

- **Over head power lines**:
  8. **Electrical hazard** from the top of the auger contacting over-head power lines making electrocution possible when moving the auger.

STATISTIC: *The majority of auger related injuries were due to entaglement at 77.7 percent, but a surprising 11 percent resulted from being pinned or struck by an auger or part of an auger.*[9]

Risk Estimation

- ***What is the severity of the possible injury and what is the probability of it occurring?***

  By our ratings the driver pulley was rated as the hazard with the highest risk. It was addressed first. The driven pulley was rated with the second highest risk so it was guarded next.

---

[9] CAISP. 2003.

Risk Evaluation

For each hazard identified, the following questions were asked:

- ***Is risk reduction required?***
  For every hazard the answer was yes.

- ***Can guarding reduce risk?***
  For all hazards the answer was yes except for the over-head power line hazard. It is difficult to guard against the auger contacting a power line. Workers must be aware of over-head power lines when moving augers. A warning decal is in place as a reminder. (**Figure 41**)

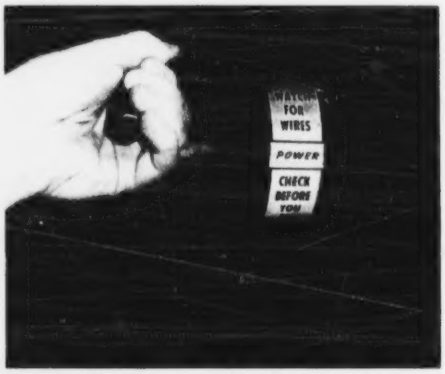

Figure 41. *The over-head wire safety decals were located near the hand winch and near the auger inlet.*

3.3 Guard Selection

The following questions were asked of each hazard:

- ***Can the guard be purchased from a dealer or wrecker?***

  The auger was old enough that existing guards were difficult to source. The existing guards were most likely removed and not re-installed because they were a hassle to remove. For the purpose of this example all guards were fabricated.

- ***Could the hazard be accessed more than once per year?***

  For the drive shaft hazard, the answer was no. In this case, a fixed guard was attached.

  The pinch point, entanglement, and friction hazard at the driver pulley may be accessed often for changing the belt or crossing over the belt to reverse the auger for clean out. The same situation occurs at the pinch point, entanglement, and friction hazards at the driven pulley. For these reasons moveable guards were decided upon.

- ***What guard classification to use?***

  The flow chart in Appendix III was used to determine the guard classification to use for the driver pulley hazard:

    - The driver pulley hazard is in a defined zone.
    - All access can be prevented.
    - The number of danger zones is high. There is the pinch point between the rotating pulley and belt, the protruding rotating shaft creates an entanglement hazard, and the exposed pulley face creates a friction hazard.
    - Therefore a (moveable) fully enclosed guard should be used.

  A similar process was used to choose a guard classification for all other hazards.

⚠ STATISTIC: *August to November are the most common months for auger related injuries to occur at 45 percent of 602 total cases in Canada from 1990 to 2000. There is also a slight rise in May at 11 percent of all cases.*[10]

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[10] CAISP. 2003.

3.4 Guard Design, Fabrication, and Attachment

Guard Design

The design details of the driver pulley guard follow.

- ***Is Viewing of the hazard required through the guard?***

  It was decided to allow viewing of the driver pulley so workers will not be inclined to remove the guard when ensuring the belt drive is operating properly. The side facing the worker will be made from expanded mesh material.

- ***Is the guard material resistant to the working environment?***

  Since the driver pulley guard will be made out of metal and the auger is exposed to the outside environment, the guard was painted.

A similar process was used to design guards for all other hazards.

Guard Fabrication

The fabrication process of the driver pulley guard follows.

- The fabrication started with the external frame. The material used was ¾ inch square tubing (0.062 in wall).
- The external walls were then constructed of 16-gauge sheet metal except the door, which was constructed of ½ in – 16 standard diamond expanded mesh. The door was reinforced with 1 in X 1/8 in flat bar around the edges. (**Figures 42 and 43**)

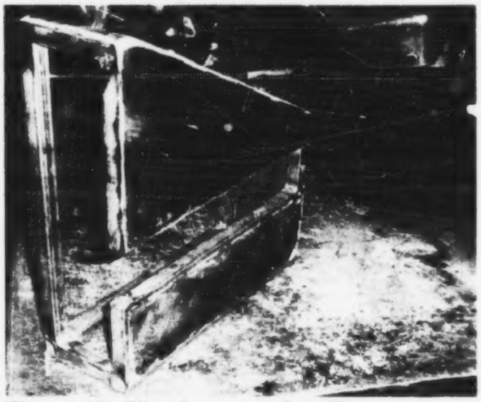

Figure 42. *The sheet metal walls.*

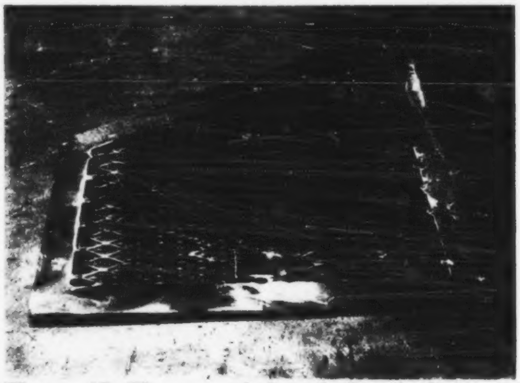

Figure 43. *The expanded mesh door before installation.*

- A 3 inch hinge purchased from a hardware store was welded to both the door and frame.
- Locating the hinge on top allowed the door to be swung up to stay out of the way for service, but then easily swung back for repositioning.
- A latch, also purchased from a hardware store, was welded to the door and the latch catch welded to the frame. (**Figure 44**)

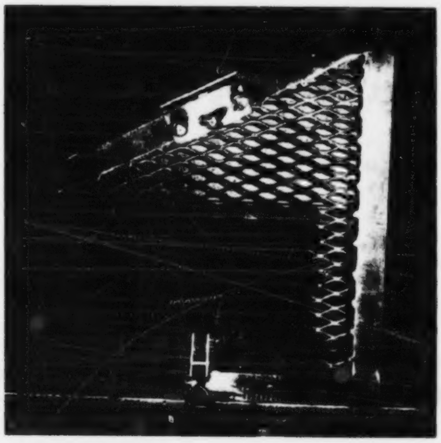

Figure 44. *The hinge and latch are installed.*

- The outsides of the guards were painted black and the hazards painted a bright yellow to draw attention to the hazard. The inside of the guards were also painted a bright yellow to draw attention to them when they are open or removed. (**Figures 45 and 46**)

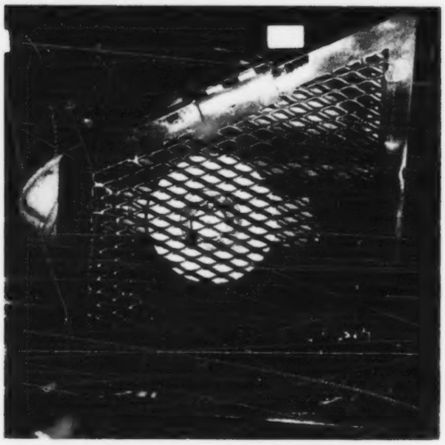

Figure 45. *Driven pulley completely guarded.*

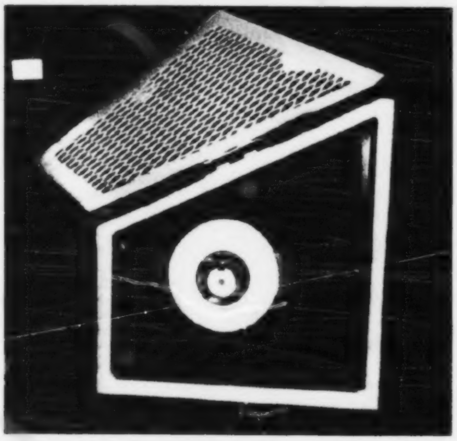

Figure 46. *The inside of the guard and hazardous components were painted.*

- A safety decal was added after painting. (**Figure 47**)

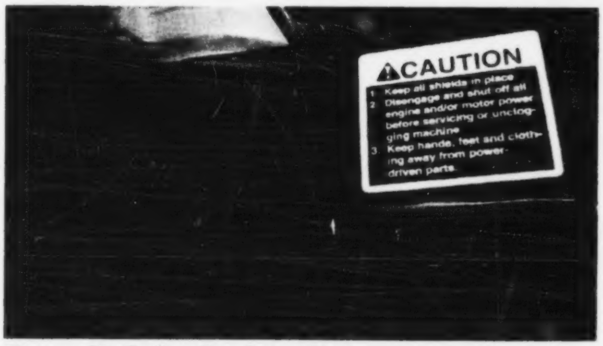
CAUTION
1 Keep all shields in place
2 Disengage and shut off all engine and/or motor power before servicing or unclogging machine
3 Keep hands, feet and clothing away from power-driven parts.

Figure 47. *Safety decal installed.*

- The tools required for fabrication were a grinder, a zip cut wheel for the grinder, welder, drill, and a hole saw bit for the drill to cut out a slot for the drive shaft to pass through the guard.

Guard Attachment

The external frame of the driver pulley guard was bolted to the motor mount frame with ¼ in bolts and nuts. (**Figure 48**)

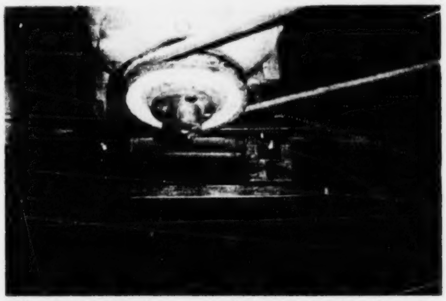

Figure 48. *The guard frame bolted to the motor mount frame.*

STATISTIC: *Augers accounted for 8.6 percent of all machinery related injuries in Canada.*[11]

3.5 Is the Machine Safe?

- A reach test was performed to test the effectiveness of each guard. (**Figure 49**) It was found that the guards were effective yet still practical.
- The auger was operated for a short time and then the guards inspected to ensure proper function.

Figure 49. *Conducting a reach test.*

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[11] CAISP. 2003.

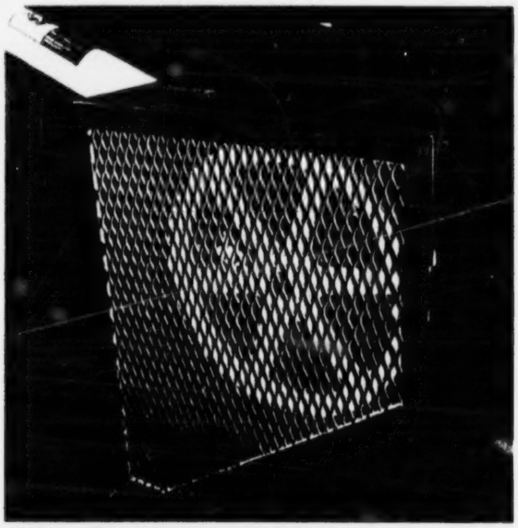

Figure 50. *The driven pulley guard.*

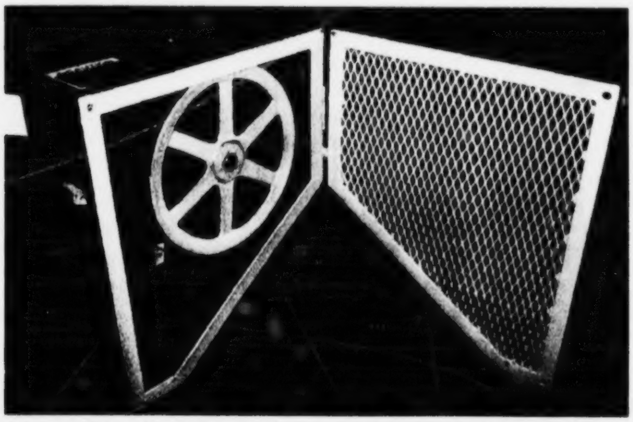

Figure 51. *The driven pulley guard with the hinged door open.*

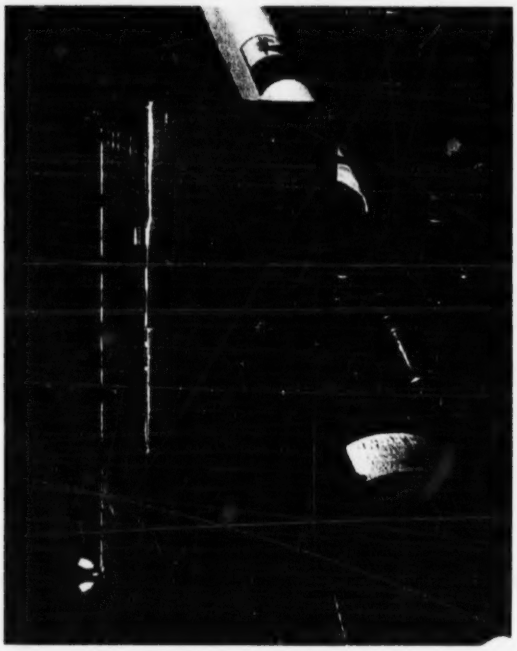

Figure 52. *The attachment of the driven pulley guard.*

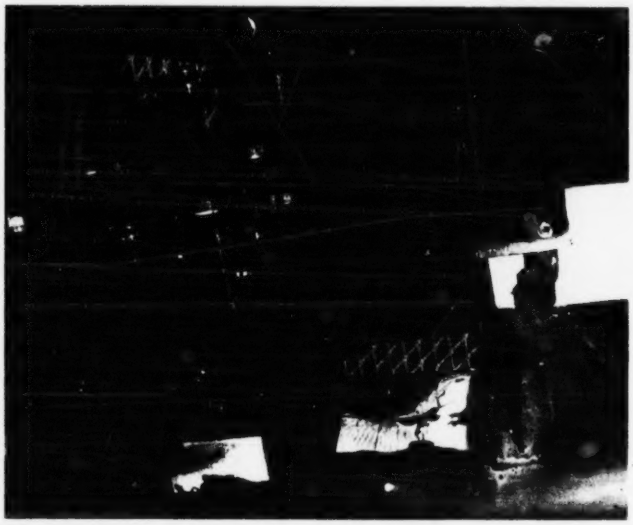

Figure 53. *The plastic drive shaft guard.*

See Table 1 on pages 32 and 33 for a copy of the completed Farm Machinery Guarding Procedure Form for the auger.

Table 1. *Example of completed Farm Machinery Guarding Procedure*

Feb17-20/04 6" Electric Auger			Humboldt, SK Joe Farmer		
1. Risk Assessment (See Section 2.2)					
1.1 What is the Function of the Machine? (See Section 2.2.1)					
Transfer grain from the inlet to the outlet.					
1.2 What Hazards Exist? (Check off) (See Section 2.2.2)					
Hazard Type	**Hazard Number and Description**				
	1: Driver pulley	2: Driven pulley	3: Drive shaft	4: Over-head power lines	5:
A) Entanglement?	✓	✓	✓		
B) Drawing-In?					
C) Pinch Points?	✓	✓			
D) Thrown Objects?					
E) Cutting?					
F) Shear?					
F) Impact?					
G) Crushing?					
H) Stabbing and Puncture?					
I) Friction?	✓	✓			
J) High-pressure injection?					
K) Heat?					
L) Electrical?				✓	
M) Other?: ________					
1.3 Risk Estimation (See Section 2.2.3)					
A) What is the severity of possible injury? (Choices: Minor=1, Severe=5, Fatal=10)	7	7	7	10	
B) What is the probability of the injury occurring? (Choices: Low=1, Medium=5, High=10)	5	3	1	2	
C) Calculate Total Risk Rating? (Safeguard highest ratings first) (Total Risk= Severity X Probability)	35	21	7	20	
1.4 Risk Evaluation (See Section 2.2.4)					
A) Is risk reduction required? (Yes=continue, No=go to step 4)	[✓ Yes] / No	[✓ Yes] / No	[✓ Yes] / No	[✓ Yes] / No	Yes / No
B) Can guarding reduce risk? (Yes=continue No=other means of safeguarding required)	[✓ Yes] / No	[✓ Yes] / No	[✓ Yes] / No	Yes / [✓ No]	Yes / No

2. Guard Type Selection (See Section 2.4.2)					
A) Can the guard be purchased from a dealer or wrecker? (No=continue, Yes=go to step 4)	Yes [✓ No]	Yes [✓ No]	Yes [✓ No]	Yes / No	Yes / No
B) Could the hazard be accessed more than once per year? (Yes=use movable guard type, No=use fixed guard type)	[✓ Yes] / No	[✓ Yes] / No	Yes [✓ No]	Yes / No	Yes / No
A) What guard classification to use?	Fully Enclosing	Fully Enclosing	Local Enclosing		
Refer to Appendix III for a selection flow chart of: Local Enclosing, Fully Enclosing, Local Distance, Fully Surrounding Distance Guard					
3. Guard Design, Fabrication, and Attachment (See Section 2.4)					
[illegible]					
A) Is viewing of the hazard required through the guard? (Yes=perforated or expanded metal, No=sheet metal, see Section 2.4.5)	[✓ Yes] / No	[✓ Yes] / No	Yes [✓ No]	Yes / No	Yes / No
B) Is the guard material resistant to the working environment? (Yes=Continue, No=paint or apply protective coating)	Yes [✓ No]	Yes [✓ No]	[✓ Yes] / No	Yes / No	Yes / No
[illegible]					
A) Is the guard durable and reliable? (Yes=continue, No=redesign to strengthen components)	[✓ Yes] / No	[✓ Yes] / No	[✓ Yes] / No	Yes / No	Yes / No
B) Are warning signs applied? (Yes=continue, No=apply warning signs, see Appendix V)	[✓ Yes] / No	[✓ Yes] / No	[✓ Yes] / No	[✓ Yes] / No	Yes / No
C) Does the guard create any additional hazards? (No=continue, Yes=redesign to reduce risk)	Yes [✓ No]	Yes [✓ No]	Yes [✓ No]	Yes / No	Yes / No
D) Can the hazard be accessed through or around the guard? (No=continue, Yes=redesign to prevent access)	Yes [✓ No]	Yes [✓ No]	Yes [✓ No]	Yes / No	Yes / No
[illegible]					
A) What attachment method is most practical in this case?	Hinged/Latched	Hinged/Latched	Bolted		
Refer to Section 2.4.4 and Appendix VI for Attachment Methods: Bolted (fixed), Hinged/Latched, Hinged/Pinned, Dowels/Pinned, Sliding/Pinned, Slot+Tab/Pinned					
B) Is the guard securely fastened? (Yes= continue, No=strengthen attachment method)	[✓ Yes] / No	[✓ Yes] / No	[✓ Yes] / No	Yes / No	Yes / No
C) Can the guard be easily removed or opened by one person? (Yes=continue, No=redesign to reduce weight or size)	[✓ Yes] / No	[✓ Yes] / No	[✓ Yes] / No	Yes / No	Yes / No
4. Is the Machine Safe? [✓ YES] / NO (No=return to step 1.2, Yes=process complete!)					

NOTE: The following information is to be used to help farm machinery owners and operators retrofit their used machinery with proper guarding. It does not replace or supersede any ASAE, CSA, OSHA, or ISO standards and is not a legal document used for law enforcement.

Table 1. *Example of completed Farm Machinery Guarding Procedure*

Feb17-20/04
6" Electric Auger

Humboldt, SK
Joe Farmer

1. Risk Assessment (See Section 2.2)

1.1 What is the Function of the Machine? (See Section 2.2.1)

Transfer grain from the inlet to the outlet.

1.2 What Hazards Exist? (Check off) (See Section 2.3)

Hazard Type	Hazard Number and Description				
	1: Driver pulley	2: Driven pulley	3: Drive Shaft	4: Over-head power lines	5:
A) Entanglement?	✓	✓	✓		
B) Drawing-In?					
C) Pinch Points?	✓	✓			
D) Thrown Objects?					
E) Cutting?					
F) Shear?					
F) Impact?					
G) Crushing?					
H) Stabbing and Puncture?					
I) Friction?	✓	✓			
J) High-pressure injection?					
K) Heat?					
L) Electrical?				✓	
M) Other?:					
1.3 Risk Estimation (See Section 2.2.3)					
A) What is the severity of possible injury? (Choices: Minor=1, Severe=5, Fatal=10)	7	7	7	10	
B) What is the probability of the injury occurring? (Choices: Low=1, Medium=5, High=10)	5	3	1	2	
C) Calculate Total Risk Rating? (Safeguard highest ratings first) (Total Risk= Severity X Probability)	35	21	7	20	
1.4 Risk Evaluation (See Section 2.2.4)					
A) Is risk reduction required? (Yes=continue, No=go to step 4)	[✓ Yes] / No	[✓ Yes] / No	[✓ Yes] / No	[✓ Yes] / No	Yes / No
B) Can guarding reduce risk? (Yes=continue No=other means of safeguarding required)	[✓ Yes] / No	[✓ Yes] / No	[✓ Yes] / No	Yes / [✓ No]	Yes / No

2. Guard Type Selection (See Section 2.4.2)					
A) Can the guard be purchased from a dealer or wrecker? (No=continue. Yes=go to step 4)	Yes [✓ No]	Yes [✓ No]	Yes [✓ No]	Yes / No	Yes / No
B) Could the hazard be accessed more than once per year? (Yes=use movable guard type. No=use fixed guard type)	[✓ Yes] No	[✓ Yes] No	Yes [✓ No]	Yes / No	Yes / No
A) What guard classification to use? Refer to Appendix III for a selection flow chart of: Local Enclosing. Fully Enclosing. Local Distance. Fully Surrounding Distance Guard	Fully Enclosing	Fully Enclosing	Local Enclosing		
3. Guard Design, Fabrication, and Attachment (See Section 2.4)					
3.1 Guard Design					
A) Is viewing of the hazard required through the guard? (Yes=perforated or expanded metal. No=sheet metal. see Section 2.4.5)	[✓ Yes] No	[✓ Yes] No	Yes [✓ No]	Yes / No	Yes / No
B) Is the guard material resistant to the working environment? (Yes=Continue. No=paint or apply protective coating)	Yes [✓ No]	Yes [✓ No]	[✓ Yes] No	Yes / No	Yes / No
3.2 Guard Fabrication					
A) Is the guard durable and reliable? (Yes=continue. No=redesign to strengthen components)	[✓ Yes] No	[✓ Yes] No	[✓ Yes] No	Yes / No	Yes / No
B) Are warning signs applied? (Yes=continue. No=apply warning signs. see Appendix V)	[✓ Yes] No	[✓ Yes] No	[✓ Yes] No	[✓ Yes] / No	Yes / No
C) Does the guard create any additional hazards? (No=continue. Yes=redesign to reduce risk)	Yes [✓ No]	Yes [✓ No]	Yes [✓ No]	Yes / No	Yes / No
D) Can the hazard be accessed through or around the guard? (No=continue. Yes=redesign to prevent access)	Yes [✓ No]	Yes [✓ No]	Yes [✓ No]	Yes / No	Yes / No
3.3 Guard Attachment to the Machine					
A) What attachment method is most practical in this case? Refer to Section 2.4.4 and Appendix VI for Attachment Methods: Bolted (fixed). Hinged/Latched. Hinged/Pinned. Dowels/Pinned. Sliding/Pinned. Slot+Tab/Pinned	Hinged / Latched	Hinged / Latched	Bolted		
B) Is the guard securely fastened? (Yes=continue. No=strengthen attachment method)	[✓ Yes] No	[✓ Yes] No	[✓ Yes] / No	Yes / No	Yes / No
C) Can the guard be easily removed or opened by one person? (Yes=continue. No=redesign to reduce weight or size)	[✓ Yes] No	[✓ Yes] No	[✓ Yes] / No	Yes / No	Yes / No
4. Is the Machine Safe? [✓ YES] / NO (No=return to step 1.2, Yes=process complete!)					

NOTE: The following information is to be used to help farm machinery owners and operators retrofit their used machinery with proper guarding. It does not replace or supersede any ASAE, CSA, OSHA, or ISO standards and is not a legal document used for law enforcement.

3.6 Materials, Time, and Money Used

A record of the materials, time, and money required was kept throughout the guarding of the auger. For the 3 guards to be fabricated it took 11.5 hours for one person and only $41.68 worth of material. So as long as you can find the time, fabricating your own guards should be inexpensive. See **Table 2** for the detailed auger guarding record.

Table 2. *Auger Guarding Record*

Hazard Number	Description	Material Used	Unit Price	Money Spent	Time Required (hrs)
1	Driver pulley	116.5 in of 3/4 in square tubing (0.062 in wall)	$0.49 / ft	$4.76	6
		2.5 in of 1.5 in X 1/4 in flat bar	$1.95 / ft	$0.41	
		242 sq in of 16 gauge sheet metal	$1.09 / sq ft	$1.83	
		46.5 in of 1 in X 1/8 in flat bar	$0.25 / ft	$0.97	
		132 sq in of 1/2 in - 16 standard diamond expanded mesh	$0.78 / sq ft	$0.72	
		2 of 1/4 in X 3/4 in bolts with nuts	$0.25 each	$0.50	
		3 in Stanley plated hinge from Peavey Mart	$1.00 each	$1.00	
		Latch from Peavey Mart	$2.00 each	$2.00	
		Safety Decal	$6.50 each	$6.50	
2	Driven pulley	126 in of 1 in X 3/16 in flat bar	$0.35 / ft	$3.68	5
		528.5 sq in of 16 gauge sheet metal	$1.09 / sq ft	$4.00	
		270 sq in of 1/2 in - 16 standard diamod expanded mesh	$0.78 / sq ft	$1.46	
		3 in Stanley plated hinge from Peavey Mart	$1.00 each	$1.00	
		2 of 3/8 in X 2 3/8 in wing bolts with nuts	$0.50 each	$1.00	
		Safety Decal	$6.50 each	$6.50	
3	Drive shaft	6 in of 3 in ID X 1/4 in wall round plastic tubing	$2.00 / ft	$1.00	0.5
		Safety Decal	$4.35 each	$4.35	
Total				**$41.68**	**11.5**

4. Questions and Answers

When is a guard required?

A guard is required when there is the possibility of harm to the operator or bystanders from a hazard.

When is a guard not required?

A guard is not required when a hazard is guarded by location. Guarded by location means that the hazard can not be physically accessed because of the design of the machine components and location of the hazard. For example, the drive shaft under a vehicle. Guards are not required for smooth shafts rotating at less than 10 rpm and smooth shaft ends protruding less than half the outside diameter of the shaft. Guarding is also not required if it interferes with machine function. **(Figure 54 and 55)**

Guarding Not Required:
would interfere with machine function

Figure 54. *A guard is not required at the discharge of this feed mixer as it would interfere with the function of the machine.*

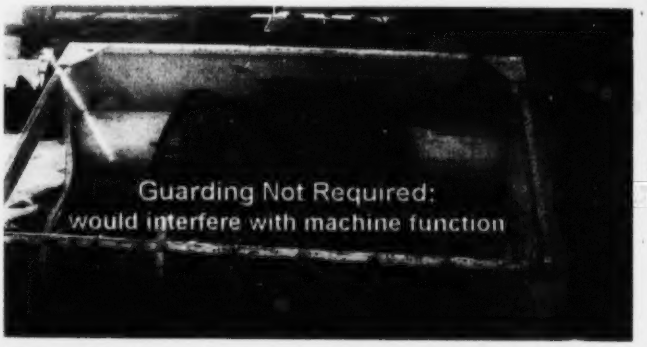

Figure 55. *A guard is not required at the inlet of this forage harvester as it would interfere with the feeding of material.*

What should I consider guarding first?

The first hazard guarded should be one which poses the greatest severity of injury and carries the most likelihood of the injury occurring. **Section 2.2** contains more information on risk assessment.

Do ground-driven components need to be guarded?

Ground-driven components need to be guarded only if operating personnel are required to be in the area while the drives are in motion.

4. Questions and Answers

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Figure 54. *A guard is not required at the discharge of this feed mixer as it would interfere with the function of the machine.*

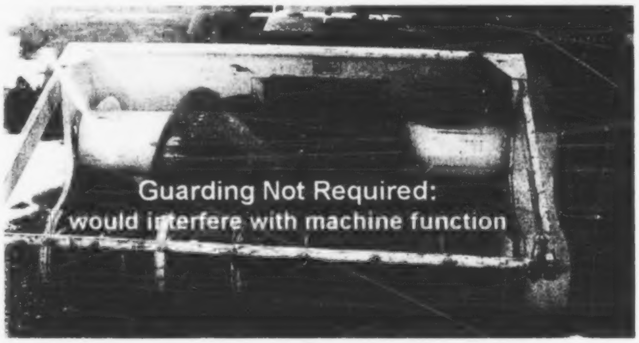

Figure 55. *A guard is not required at the inlet of this forage harvester as it would interfere with the feeding of material.*

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Ground-driven components need to be guarded only if operating personnel are required to be in the area while the drives are in motion.

What types of hazards should I look to guard?

Any mechanical hazard such as rotating shafts, nip points, gears, pinching hazards, shearing hazards, pulleys, sheaves, and sprockets. Hot surfaces and electrical hazards should also be guarded. **Section 2.3** contains more information on types of hazards.

What material should I use when fabricating a guard?

Most guards are made of metal as they provide the best durability and protection from the environment. Solid sheet metal, expanded mesh, or perforated metal are common materials used. Thin walled round tubing provides good structural support. **Section 2.4.5** contains a list of recommended materials.

How should I attach the guard?

The guard should be securely attached so that inadvertent contact does not damage or dislodge the guard. Frequency of access to the hazard is important in deciding how to attach the guard. If minimal access is required, attach the guard using bolts or screws. If frequent access is required, consider hinging the guard and using a latch that can be operated by hand. See **Appendix VI** for a list of suggested guard attachment components.

PAMI Recommendation:
If access to the hazard is required only once per year for maintenance use a fixed guard that is attached by fasteners, which require tools. If the hazard being guarded requires access more than once per year for maintenance or adjustment use a moveable guard that is easily removed or opened and reinstalled. Use fasteners and latches that stay attached to the guard or machine so they are not lost when removed. These considerations will increase the likelihood of the guard being reinstalled after removal.

Where can I purchase safety-warning decals?

Safety warning decals can be purchased from any major agricultural equipment dealer or safety supply companies. See **Appendix V** for a list of useful safety decals.

Appendix I
Related Standards

Safety of Machinery – Guards – General Requirements for the Design and Construction of Fixed and Moveable Guards, ISO Standard 14120, First Edition 2002-02-01

Guarding for Agricultural Equipment, ANSI/ASAE Standard S493.1 JUL03

Safeguarding of Machinery – Occupational Health and Safety, CSA Standard Z432-94, July 1994

Guarding of Farm Equipment, Farmstead Equipment, and Cotton Gins, U.S. Department of Labour, Occupational Safety and Health Administration Standard 1928.57

Standards can be ordered from:

American Society of Agricultural Engineers (ASAE)
2950 Niles Rd, St. Joseph, MI 49085-9659
Phone: 616-429-0300 Fax: 616-429-3852
Email: hq@asae.org
Website: http://www.asae.org

Canadian Standards Association (CSA)
5060 Spectrum Way, Mississauga, ON L4W 5N6
Phone: 1-800-463-6727 (Canada and US) or 416-747-4044
Fax: 416-747-2510
Email: sales@csa.ca
Website: http://www.csa.ca

International Organization for Standardization (ISO)
1, Varembe Street, Postal Box 56
CH-1211 Geneva 20, Switzerland
Phone: +41 22 749 01 11 Fax: +41 22 733 34 30
Website: http://www.iso.ch/iso/en/ISOOnline.frontpage
NOTE: In Canada, puchase standards at IHS Canada website and e-mail
Email: gic@ihscanada.ca
Website: http://www.ihscanada.ca

U.S. Department of Labour / Occupational Safety and Health Administration (OSHA)
OSHA Publications
P.O. Box 37535 Washington, D.C. 20013-7535
Telephone: (202) 693-1888
Fax: (202) 693-2498
Website: http://www.osha.gov

Appendix II
Glossary of Terms

ASAE: American Society of Agricultural Engineers

CSA: Canadian Standards Association

CAISP: Canadian Agricultural Injury Surveillance Program

Danger: A state of condition in which personal injury is reasonably foreseeable.

Danger zone: The zone around the machine (front, back, sides, top, and bottom) where a hazard is created by the motion of the machine components.

Distance guard: A guard that does not completely enclose a danger zone, but which prevents or reduces access by virtue of its dimensions and its distance from the danger zone.

Enclosing guard: A guard that prevents access to the danger zone from all sides.

Fixed guard: A guard kept in place either permanently or by means of fasteners, making removal / opening impossible without using tools.

Ground-driven components: Components, which are powered by the forward or rearward motion of equipment traveling over the ground.

Guard: A physical barrier that prevents access to a danger zone.

Guarded by location: A hazard is guarded by location when it is guarded by other parts or components of the machine that are not themselves guards, or when the hazard is beyond the safety distance.

Hazard: A situation that may cause injury to a person.

Hot surface: A surface which reaches operating temperatures in excess of 130 °C (266 °F) and which could involve injury by inadvertent contact.

Inadvertent contact: Unplanned contact between a person and a hazard, resulting from the person's actions during normal operation or servicing of equipment.

ISO: International Standards Organization

Machinery: Apparatus for producing or applying power, having fixed or moving parts each with definite functions. This includes powered and non-powered machinery such as pulled implements. The term machinery also includes stationary equipment such as seed processing machinery and livestock handling equipment.

Machinery hazard: Machinery parts, which can cause injury upon direct contact or by entanglement of personal apparel. This includes, but is not limited to, pinch points, nip points, and projections on rotating parts.

Moveable guard: A guard generally connected by mechanical means to the machine frame or an adjacent fixed element and which can be opened without the use of tools.

Nip-point: A type of pinch point characteristic of components such as meshing gears and the run-on point where a belt, chain, or cable contacts a sheave, sprocket or idler.

Operator: Any person responsible for the operation of the equipment.

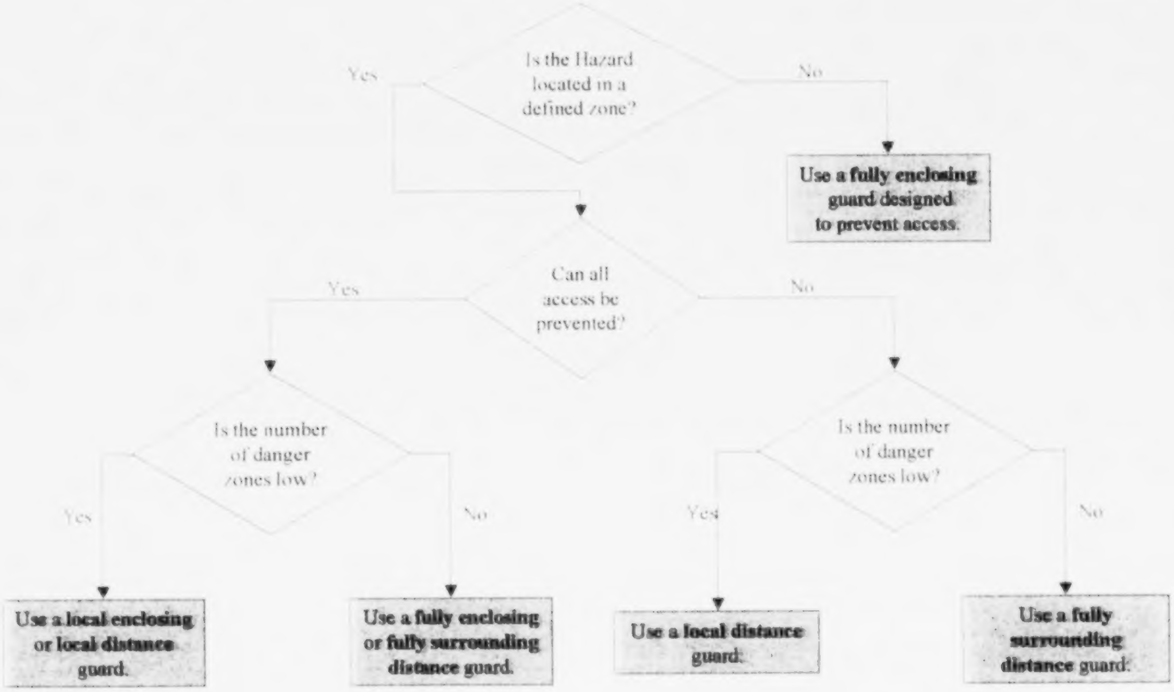
OSHA: Occupational Safety and Health Administration, United States Department of Labour

Risk: A combination of the probability of injury and the degree of injury.

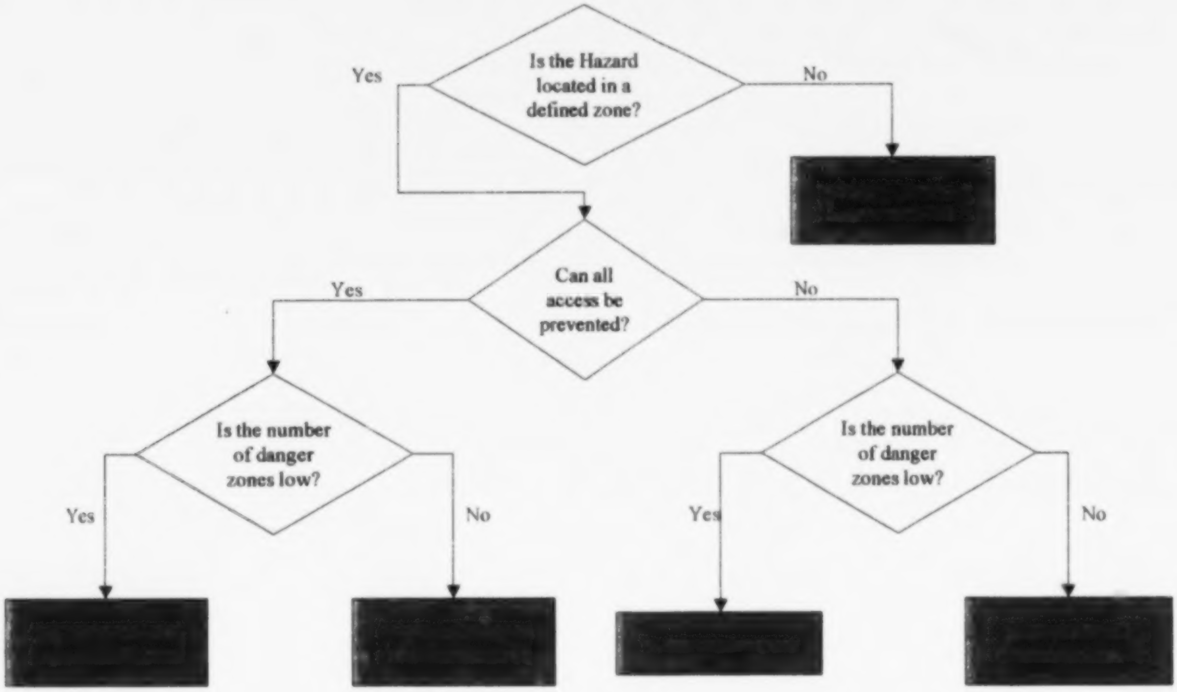
Safeguard: A guard or device designed to protect persons from danger.

Safety distance guarding: A method of providing guarding where the possibility of inadvertent contact with the hazard is minimized by the combination of the guard configuration (including openings) and the distance between the guard and the hazard. An additional aspect includes separation dimensions of pinch points in relation to body parts.

Appendix III
Guard Classification Flow Chart


Is the Hazard located in a defined zone?
Yes
No
Use a fully enclosing guard designed to prevent access.
Can all access be prevented?
Yes
No
Is the number of danger zones low?
Yes
No
Is the number of danger zones low?
Yes
No
Use a local enclosing or local distance guard.
Use a fully enclosing or fully surrounding distance guard.
Use a local distance guard.
Use a fully surrounding distance guard.

Appendix III
Guard Classification Flow Chart


Is the Hazard located in a defined zone?
Yes
No
Can all access be prevented?
Yes
No
Is the number of danger zones low?
Yes
No
Is the number of danger zones low?
Yes
No

Appendix IV
Safety Distance Guarding

Reach Over Barriers

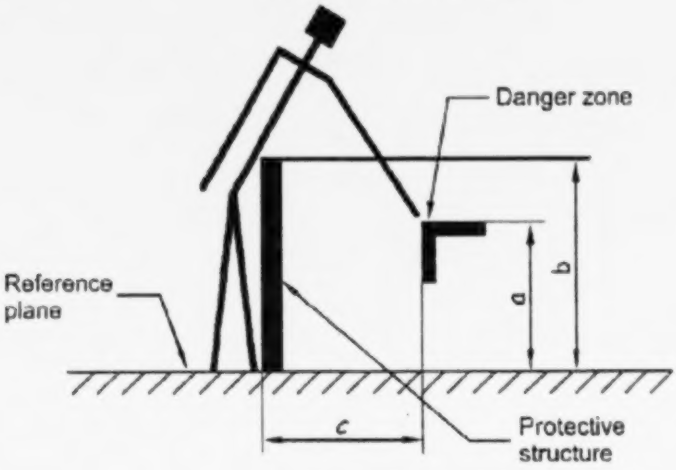


Figure 3

Table 1
Reach Over Barriers

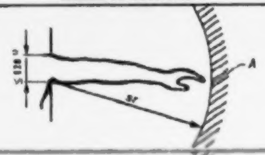
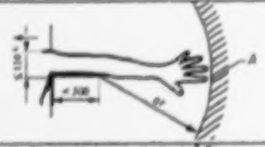
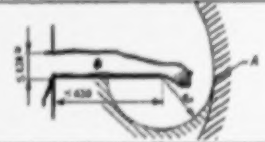
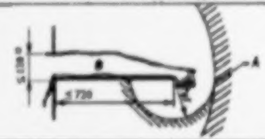
Dimensions in Millimeters

Height of danger zone, *a*	**Height of protective structure, *b*1)**								
	1 000	1 200	1 400	1 600	1 800	2 000	2 200	2 400	2 500
	Horizontal distance to danger zone, *c*								
2 500 2)	-	-	-	-	-	-	-	-	-
2 400	100	100	100	100	100	100	100	100	-
2 200	600	600	500	500	400	350	250	-	-
2 000	1 100	900	700	600	500	350	-	-	-
1 800	1 100	1000	900	900	600	-	-	-	-
1 600	1 300	1000	900	900	500	-	-	-	-
1 400	1 300	1000	900	800	100	-	-	-	-
1 200	1 400	1000	900	500	-	-	-	-	-
1 000	1 400	1000	900	300	-	-	-	-	-
800	1 300	900	600	-	-	-	-	-	-
600	1 200	500	-	-	-	-	-	-	-
400	1 200	300	-	-	-	-	-	-	-
200	1 100	200	-	-	-	-	-	-	-
0	1 100	200	-	-	-	-	-	-	-

NOTE: Reprinted with permission of the American Society of Agricultural Engineers, ANSI/ASAE S493.1 JUL03 Guarding for Agricultural Equipment

Table 2
Extent of Reach Around Barrier

Dimensions in millimeters

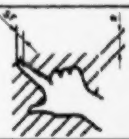
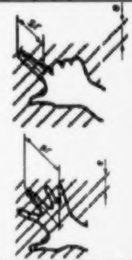
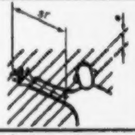
Limitation of Movement	Safety Distance, sr	Illistration
Limitation of movement only at shoulder and armpit	≥ 850	
Arm supported up to elbow	≥ 550	
Arm supported up to wrist	≥ 230	
Arm and hand supported up to knuckle joint	≥ 130	

A is the range of movement of the arm

1) This is either the diameter of a round opening, or the side of a square opening, or the width of a slot opening.

Table 3
Inside Reach Through Guards

Dimensions in millimeters

Part of Body	Illustration	Opening	Safety distance, sr		
			Slot	Square	Round
Finger tip		$e \leq 4$	≥ 2	≥ 2	≥ 2
		$4 < e < 6$	> 10	> 5	> 5
Finger up to knuckle joint Or hand		$6 < e \leq 8$	≥ 20	≥ 15	≥ 5
		$8 < e \leq 10$	≥ 80	≥ 25	≥ 20
		$10 < e \leq 12$	≥ 100	≥ 80	≥ 80
		$12 < e \leq 20$	≥ 120	≥ 120	≥ 120
		$20 < e \leq 30$	≥ 850	≥ 120	≥ 120
Arm up to junction with shoulder		$30 < e \leq 40$	≥ 850	≥ 200	≥ 120
		$40 < e \leq 120$	≥ 850	≥ 850	≥ 850

1) If the length of the slot opening is ≤ 65 mm, the thumb will act as a stop and the safety distance can be reduced to 200 mm.

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Appendix V
Safety Decal Guide

Make	Part Number	Price (Can$)	Description
[redacted]	E82510	$6.50	Caution, keep guards in place
	E82514	$4.35	Danger, entanglement in rotating driveline can cause serious injury or death
	H209453	$8.50	Danger, do not open cleanout doors with engine running
	H149096	$8.50	Warning, stay clear of flying objects while engine is running
	H149099	$6.50	Warning, never raise shield while engine is running
	H149067	$9.75	Warning, high pressure fluid injection
	H169344	$7.00	Warning, hot liquid under pressure
	H149062	$8.00	Danger, do not enter grain tank while engine is running
	H151397	$4.75	Caution, avoid contact with rotating auger
[redacted]	181595A1	$9.22	Warning, do not open until all mechanisms have stopped
	144388A1	$9.21	Warning, stay clear of flying objects while engine is running
	144383A1	$9.22	Danger, do not enter grain tank while engine is running
	144386A1	$9.55	Danger, keep hand out of auger sump while engine is running
	144385A1	$5.06	Warning, shields are provided to guard these moving parts
	181475A1	$9.22	Warning, contact with belt may engage drive, stop engine
	181597A1	$9.22	Warning, do not enter drive area while engine is running
	191129A1	$5.06	Warning, avoid injury. Shut off engine before adjusting or servicing
AGCO	71379128	$4.39	Warning, keep shields in place
	71379126	$3.87	Warning, escaping fluid under pressure can penetrate skin
	111670W1	$1.03	Warning, do not open until engine and all movement have stopped
	111091W1	$1.38	Danger, shield missing do not operate
	71379127	$2.54	Warning, stay clear of flying objects while engine is running
	111737W1	$1.73	Warning, stop engine and wait for all movement to stop before servicing chopper
	111743W1	$0.72	Warning, keep hands away from cleanout opening when engine is running
	111736W1	$2.87	Danger, stop engine and remove key before entering grain tank
	713112163	$16.63	Warning, keep out of engine compartment while engine is running
	3609336M1	$5.82	Warning, high pressure steam and hot water
New Holland	267065	$2.83	Warning, rotating augers. Do not enter grain tank when machine is operating
	684145	$4.88	Warning, stand clear, rotating flails under hood: crop material exiting at high speed
	703810	$3.23	Warning, rotating parts under this cover
	703810	$3.23	Warning, rotating parts under this cover may continue to rotate
	684145	$4.88	Warning, Stand clear, Rotating flails under hood
Note: Prices were at the time this guide was written (2003), see your local dealer for more information.			

Appendix V
Safety Decal Guide

Make	Part Number	Price (Can$)	Description
John Deere	E82510	$6.50	Caution. keep guards in place
	E82514	$4.35	Danger entanglement in rotating driveline can cause serious injury or death
	H209453	$8.50	Danger do not open cleanout doors with engine running
	H149096	$8.50	Warning. stay clear of flying objects while engine is running
	H149099	$6.50	Warning. never raise shield while engine is running
	H149067	$9.75	Warning. high pressure fluid injection
	H169344	$7.00	Warning. hot liquid under pressure
	H149062	$8.00	Danger do not enter grain tank while engine is running
	H151397	$4.75	Caution. avoid contact with rotating auger
[redacted]	181595A1	$9.22	Warning. do not open until all mechanisms have stopped
	144388A1	$9.21	Warning. stay clear of flying objects while engine is running
	144383A1	$9.22	Danger do not enter grain tank while engine is running
	144386A1	$9.55	Danger. keep hand out of auger sump while engine is running
	144385A1	$5.06	Warning. shieids are provided to guard these moving parts
	181475A1	$9.22	Warning, contact with belt may engage drive. stop engine
	181597A1	$9.22	Warning. do not enter drive area while engine is running
	191129A1	$5.06	Warning, avoid injury. Shut off engine before adjusting or servicing
AGCO	71379128	$4.39	Warning, keep shieids in place
	71379126	$3.87	Warning, escaping fluid under pressure can penetrate skin
	111670W1	$1.03	Warning, do not open until engine and all movement have stopped
	111091W1	$1.38	Danger. shield missing do not operate
	71379127	$2.54	Warning, stay clear of flying objects while engine is running
	111737W1	$1.73	Warning, stop engine and wait for all movement to stop before servicing chopper
	111743W1	$0.72	Warning, keep hands away from cleanout opening when engine is running
	111736W1	$2.87	Danger, stop engine and remove key before entering grain tank
	713112163	$16.63	Warning. keep out of engine compartment while engine is running
	3609336M1	$5.82	Warning. high pressure steam and hot water
New Holland	267065	$2.83	Warning. rotating augers. Do not enter grain tank when machine is operating
	684145	$4.88	Warning. stand clear. rotating flails under hood. crop material exiting at high speed
	703810	$3.23	Warning, rotating parts under this cover
	703810	$3.23	Warning, rotating parts under this cover may continue to rotate
	684145	$4.88	Warning. Stand clear. Rotating flails under hood
Note. Prices were at the time this guide was written (2003), see your local dealer for more information			

Appendix VI
Guard Attachment Component Guide

Make	Part Number	Quantity	Price (Can$)	Description
[redacted]		1		**Dowels/Pinned attachment**
	AH164852	1	$5.25	Lynch pin with tether
[redacted]		1		**Hinged/Latch attachment**
	A44990	1	$2.35	Rubber Latch
	H141549	1	$7.00	Angle
	03M7251	1	$0.13	Bolt (M6X12)
	14M7303	1	$0.25	Nut (M6)
[redacted]		1		**Hinged/Latch attachment**
	AH167973	1	$18.50	Latch kit
[redacted]		1		**Hinged/Latch attachment**
	H132708	1	$12.75	Mounting Bracket
	H130930	1	$9.25	Spring latch
	19M7784	1	$0.25	Cap Screw (M10X20)
	14M7296	1	$0.50	Flange nut (M10)
[redacted]		1		**Hinged/Latch attachment**
	L105124	1	$8.22	Hook for latch
	470-11012	2	$0.68	Screw - machine, pan head slotted, No 10NC X 3/4in
	231-51409	2	$0.64	Nut - hex serrated flange, No 10 NC
	188103C1	1	$8.35	Bracket - Latch anchor
	494307C1	1	$4.32	Rubber Latch
	432-812	1	$0.74	Cotter Pin, 1/8 X 3/4in
	439-1412	1	$1.07	Pin - headed, 1/4 X 3/4in, grade 2
	439-1424	1	$1.47	Pin - headed, 1/4 X 1.5in, grade 2
New Holland		1		**Hinged/Latch attachment**
	350918	1	$7.71	Mounting Bracket
	353067	1	$10.98	Rubber latch
	453857	1	$5.26	Clip for latch
AGCO		1		**Hinged/Latch attachment**
	101232M1	1	$19.23	Stop Bracket, Guard
	101231M1	1	$27.29	Bracket, Latch
	7025075	1	$6.65	Bracket, Catch
	1787520W1	1	$3.92	Anchor bracket, Rubber latch
	776682	1	$5.36	Hook, Rubber

Note: Prices listed were at the time this guide was written (2003). See your local dealer for accurate pricing.

Appendix VII
Farm Machinery Guarding Procedure

Farm Machinery Guarding Procedure					
Date:		**Location:**			
Machine:		**Persons performing procedure:**			
1. Risk Assessment (See Section 2.2)					
1.1 What is the Function of the Machine? (See Section 2.2.1)					
1.2 What Hazards Exist? (Check off) (See Section 2.3)					
Hazard Type	**Hazard Number and Description**				
	1: ______	2: ______	3: ______	4: ______	5: ______
A) Entanglement?					
B) Drawing-In?					
C) Pinch Points?					
D) Thrown Objects?					
E) Cutting?					
F) Shear?					
F) Impact?					
G) Crushing?					
H) Stabbing and Puncture?					
I) Friction?					
J) High-pressure injection?					
K) Heat?					
L) Electrical?					
M) Other?: ______					
1.3 Risk Estimation (See Section 2.2.3)					
A) What is the severity of possible injury? (Choices: Minor=1, Severe=5, Fatal=10)					
B) What is the probability of the injury occurring? (Choices: Low=1, Medium=5, High=10)					
C) Calculate Total Risk Rating? (Safeguard highest ratings first) (Total Risk= Severity X Probability)					
1.4 Risk Evaluation (See Section 2.2.4)					
A) Is risk reduction required? (Yes=continue, No=go to step 4)	Yes / No	Yes / No	Yes / No	Yes / No	Yes / No
B) Can guarding reduce risk? (Yes=continue No=other means of safeguarding required)	Yes / No	Yes / No	Yes / No	Yes / No	Yes / No

Appendix VI
Guard Attachment Component Guide

Make	Part Number	Quantity	Price (Can$)	Description
John Deere		**1**		**Dowels/Pinned attachment**
	AH164852	1	$5.25	Lynch pin with tether
John Deere		**1**		**Hinged/Latch attachment**
	A44990	1	$2.35	Rubber Latch
	H141549	1	$7.00	Angle
	03M7251	1	$0.13	Bolt (M6X12)
	14M7303	1	$0.25	Nut (M6)
John Deere		**1**		**Hinged/Latch attachment**
	AH167973	1	$18.50	Latch kit
John Deere		**1**		**Hinged/Latch attachment**
	H132708	1	$12.75	Mounting Bracket
	H130930	1	$9.25	Spring latch
	19M7784	1	$0.25	Cap Screw (M10X20)
	14M7296	1	$0.50	Flange nut (M10)
[redacted]		**1**		**Hinged/Latch attachment**
	L105124	1	$8.22	Hook for latch
	470-11012	2	$0.68	Screw - machine, pan head slotted, No 10NC X 3/4in
	231-51409	2	$0.64	Nut - hex serrated flange, No 10 NC
	188103C1	1	$8.35	Bracket - Latch anchor
	494307C1	1	$4.32	Rubber Latch
	432-812	1	$0.74	Cotter Pin, 1/8 X 3/4in
	439-1412	1	$1.07	Pin - headed, 1/4 X 3/4in, grade 2
	439-1424	1	$1.47	Pin - headed, 1/4 X 1.5in, grade 2
New Holland		**1**		**Hinged/Latch attachment**
	350918	1	$7.71	Mounting Bracket
	353067	1	$10.98	Rubber latch
	453857	1	$5.26	Clip for latch
AGCO		**1**		**Hinged/Latch attachment**
	101232M1	1	$19.23	Stop Bracket, Guard
	101231M1	1	$27.29	Bracket, Latch
	7025075	1	$6.65	Bracket, Catch
	1787520W1	1	$3.92	Anchor bracket, Rubber latch
	776682	1	$5.36	Hook, Rubber
Note: Prices listed were at the time this guide was written (2003). See your local dealer for accurate pricing.				

Appendix VII
Farm Machinery Guarding Procedure

Farm Machinery Guarding Procedure					
Date:			**Location:**		
Machine:			**Persons performing procedure:**		
1. Risk Assessment (See Section 2.2)					
1.1 What is the Function of the Machine? (See Section 2.2.1)					
1.2 What Hazards Exist? (Check off) (See Section 2.3)					
Hazard Type	**Hazard Number and Description**				
	1: ______	2: ______	3: ______	4: ______	5: ______
A) Entanglement?					
B) Drawing-In?					
C) Pinch Points?					
D) Thrown Objects?					
E) Cutting?					
F) Shear?					
F) Impact?					
G) Crushing?					
H) Stabbing and Puncture?					
I) Friction?					
J) High-pressure injection?					
K) Heat?					
L) Electrical?					
M) Other?					
1.3 Risk Estimation (See Section 2.2.3)					
A) What is the severity of possible injury? (Choices Minor=1, Severe=5, Fatal=10)					
B) What is the probability of the injury occurring? (Choices Low=1, Medium=5, High=10)					
C) Calculate Total Risk Rating? (Safeguard highest ratings first) (Total Risk= Severity X Probability)					
1.4 Risk Evaluation (See Section 2.2.4)					
A) Is risk reduction required? (Yes=continue, No=go to step 4)	Yes / No	Yes / No	Yes / No	Yes / No	Yes / No
B) Can guarding reduce risk? (Yes=continue No=other means of safeguarding required)	Yes / No	Yes / No	Yes / No	Yes / No	Yes / No

2. Guard Type Selection (See Section 2.4.2)					
A) Can the guard be purchased from a dealer or wrecker? (No=continue, Yes=go to step 4)	Yes / No	Yes / No	Yes / No	Yes / No	Yes / No
B) Could the hazard be accessed more than once per year? (Yes=use movable guard type, No=use fixed guard type)	Yes / No	Yes / No	Yes / No	Yes / No	Yes / No
A) What guard classification to use?					
Refer to Appendix III for a selection flow chart of: Local Enclosing, Fully Enclosing, Local Distance, Fully Surrounding Distance Guard					
3. Guard Design, Fabrication, and Attachment (See Section 2.4)					
3.1 Guard Design					
A) Is viewing of the hazard required through the guard? (Yes=perforated or expanded metal, No=sheet metal, see Section 2.4.5)	Yes / No	Yes / No	Yes / No	Yes / No	Yes / No
B) Is the guard material resistant to the working environment? (Yes=Continue, No=paint or apply protective coating)	Yes / No	Yes / No	Yes / No	Yes / No	Yes / No
3.2 Guard Fabrication					
A) Is the guard durable and reliable? (Yes=continue, No=redesign to strengthen components)	Yes / No	Yes / No	Yes / No	Yes / No	Yes / No
B) Are warning signs applied? (Yes=continue, No=apply warning signs, see Appendix V)	Yes / No	Yes / No	Yes / No	Yes / No	Yes / No
C) Does the guard create any additional hazards? (No=continue, Yes=redesign to reduce risk)	Yes / No	Yes / No	Yes / No	Yes / No	Yes / No
D) Can the hazard be accessed through or around the guard? (No=continue, Yes=redesign to prevent access)	Yes / No	Yes / No	Yes / No	Yes / No	Yes / No
3.3 Guard Attachment to the Machine					
A) What attachment method is most practical in this case?					
Refer to Section 2.4.4 and Appendix VI for Attachment Methods: Bolted (fixed), Hinged/Latched, Hinged/Pinned, Dowels/Pinned, Sliding/Pinned, Slot+Tab/Pinned					
B) Is the guard securely fastened? (Yes= continue, No=strengthen attachment method)	Yes / No	Yes / No	Yes / No	Yes / No	Yes / No
C) Can the guard be easily removed or opened by one person? (Yes=continue, No=redesign to reduce weight or size)	Yes / No	Yes / No	Yes / No	Yes / No	Yes / No
4. Is the Machine Safe? YES / NO (No=return to step 1.2, Yes=process complete!)					

NOTE: The above information is to be used to help farm machinery owners and operators retrofit their used machinery with proper guarding. It does not replace or supersede any CSA, ASAE, OSHA, or ISO standards that are updated on a regular basis; nor is it a legal document to be used for law enforcement. Should you have any specific questions, your should consult with a Farm Safety Organization (see list of organizations on back cover of this publication) or other qualified people.

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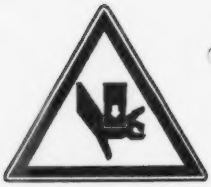
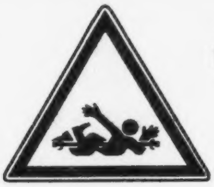
Locker, A.R., J.L. Dorland, L. Hartling, and W. Pickett. 2003. *Economic Burden of Agricultural Machinery Injuries in Ontario, 1985 to 1996*. Rural Health Research. 19 (3) 285 - 291.

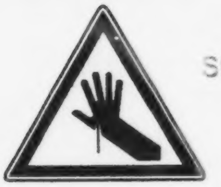
Hazard Symbol Glossary



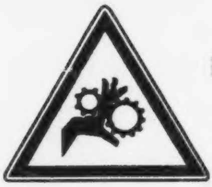
Crushing Hazard



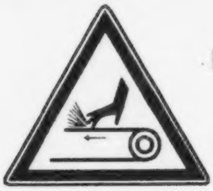
Entanglement Hazard



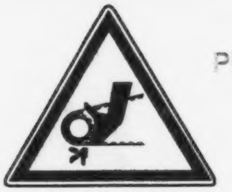
Stabbing and Puncture Hazard



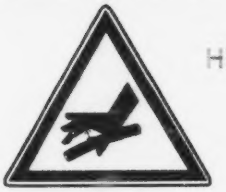
Drawing-in Hazard



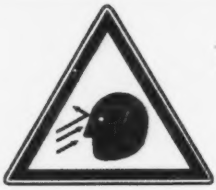
Friction and Abrasion Hazard



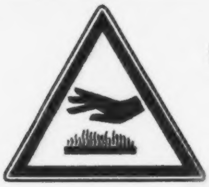
Pinch Point Hazard



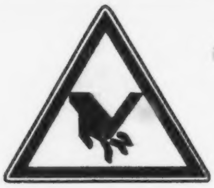
High Pressure Injection Hazard



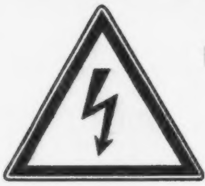
Thrown Objects Hazard



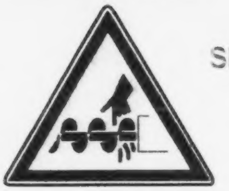
Heat Hazard



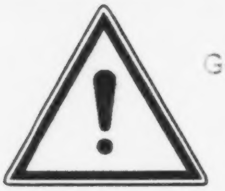
Cutting Hazard



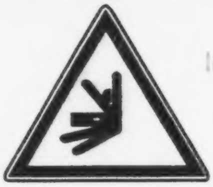
Electrical Hazard



Shear Hazard



General Warning Hazard



Impact Hazard

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Farm Safety Organizations

Canada:

Canadian Agricultural Safety Association (CASA)
Saskatoon, SK
www.casa-acsa.ca

Provincial:

Alberta
Wild Rose Agricultural Producers
Edmonton, AB
www.wrap.ab.ca

British Columbia
Farm and Ranch Safety and Health Association (FARSHA)
Langley, BC
www.farsha.bc.ca

Manitoba
Provincial Farm Safety Co-ordinator
MAFRI, and MB Labour and Immigration
Winnipeg, MB
Ph: 204/945-2315
www.gov.mb.ca/agriculture/farmsafety

New Brunswick
The Agriculture Producers Association of NB Inc.
Fredericton, NB
www.nbfarm.com

Newfoundland
Newfoundland and Labrador Federation of Agriculture
Mount Pearl, NL
www.netfx.ca/nlfa

Nova Scotia
Nova Scotia Farm Health and Safety Committee
Truro, NS
www.gov.ns.ca/nsaf/ohs/

Ontario
Farm Safety Association Inc.
Guelph, ON
www.fsai.on.ca

Prince Edward Island
PEI Federation of Agriculture
Charlottetown, PE
www.virtuo.com/peifa/

Quebec
L'Union des producteurs agricoles
Longueuil, QC
www.upa.qc.ca

Saskatchewan
Saskatchewan Alliance
Saskatoon, SK
www.iareh.usask.ca/rhep/aghealth.php

Prairie Agricultural Machinery Institute (PAMI)
Humboldt, SK and Portage la Prairie, MB
www.pami.ca
e-mail: pami@sasktel.net

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